PROCEEDINGS of the I.R.E. AND WAVES and ELECTRONS

Published Monthly
by
The Institute of Radio Engineers, Inc.

March, 1946

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George R. Town

Chairman—Rochester Section

George R. Town was born on May 26, 1905, in Poultney, Vermont. He received the degree of E.E. from Rensselaer Polytechnic Institute in 1926, and the degree of D.Eng. from the same institution in 1929.

From 1929 until 1933 he was an engineer in the research laboratory at Leeds and Northrup Company. For seven months in 1933 he was a development engineer for Arma Engineering Company. From 1933 to 1936 he was an instructor at Rensselaer Polytechnic Institute serving one year as instructor in mathematics, and two years as instructor in electrical engineering.

In 1936 Dr. Town joined the engineering division of Stromberg-Carlson Company. He has worked successively as an engineer in the research department, as engineer-in-charge of the television laboratory, as assistant director of research, and in his present position as manager of engineering and research. In April, 1945, he was elected assistant secretary of the Company. He has served on various panels and committees of the National Television System Committee and of the Radio Technical Planning Board, being chairman of one of the Television Standards Committees of the latter organization. He is, at present, chairman of the Frequency-Modulation Systems Committee of the Radio Manufacturers Association, and secretary of the RMA Television Systems Committee.

He was secretary of the Rochester Section from 1942 to 1944, and has served as chairman for the Rochester Section since 1944. He is chairman of the I.R.E. Committee on Organizational Research, and is a member of the I.R.E. Committee on Education. He is vice-chairman of the Rochester Section of the American Institute of Electrical Engineers.

Dr. Town joined the Institute of Radio Engineers as an Associate in 1937 and transferred to Senior Member grade in 1944.

Contributing substantially to the advancement of the radio-and-electronic field are the various periodicals which present the methods and advances in that field. Their Editors are a group of leaders of thought in the field. Guest editorials from the pens of these Editors have been requested, and it is accordingly possible to present below an analytical and stimulating discussion from the Editor of *Electronic Industries*, who is himself a Fellow of The Institute of Radio Engineers and a former Federal Radio Commissioner.

The Editor

When Radio Engineer is "Big Boss"

ORESTES H. CALDWELL

Radio engineers can be proud of the industrial wealth they have created and continue to create.

Last year, for example, some four-billion-dollars' worth of radio equipment and service—four-thousand-million dollars—was produced based on the technical discoveries and designs created by the members of The Institute of Radio Engineers and their fellow engineers. For each of the voting members of the I.R.E., this was nearly one and one-half million dollars per man. And all of this billions of dollars of actual wealth per year was created literally "out of thin air" by radio engineers and radio inventors.

Radio engineers have now had a taste of big-scale industrial production. Radio engineers have seen themselves playing a part in big-business operations. They have observed that their knowledge and their efforts are at the center of businesses which collect hard round dollars in the millions.

But from now on, we should insist, radio engineers must not be satisfied to be merely employees and staff aides in the huge industries they have created.

Radio engineers should themselves take business and industrial leadership. It is time for the radio engineer to be the "big boss" of his own concern and shape its general policies. Instead of avoiding and evading business responsibility in order to keep close to the design room and slide-rule, radio engineers should prepare to reach out themselves for the top management positions, for independent proprietorships, for public service in fitting radio into broader usefulness to humanity.

All too often, some skillful lawyer, clever salesman, or quick-minded accountant is chosen to fill the top place in a radio organization, a post which would have been far better served by a trained radio-minded man having the broad grasp necessary to relate our radio art to general business problems.

Radio engineers are perfectionists. And so they like to keep close to their technical work, improving detail parts into the highest possible efficiency.

But even from this aspect of perfectionism alone, radio men will admit that fullest perfection in radio cannot come unless the radio engineer has the greatest freedom in which to work. And this means that there must be radio engineers at the top who can give sympathetic encouragement to radio engineers throughout the organization.

Radio engineers have created a whole galaxy of great industries—industries tremendous in public service, industries imagination-defying in technical achievement, and industries now astronomic in dollar volume!

Let us look forward to the day when radio-electronic industries are officered by radio men, from top executive posts on down to the design rooms and production departments. This is absolutely necessary, for the good of the radio industries and the public they serve. Let radio men accept and even seek out these responsibilities of management and direction. And let us see that the radio man collects in full, for himself and his family, his share of the wealth he is producing.

Induction Heating in Radio Electron-Tube Manufacture*

EDWIN E. SPITZER†, SENIOR MEMBER, I.R.E.

Summary—The radio electron-tube industry was one of the first to use induction heating extensively. The metal parts of electron tubes must be heated to 500 to 1500 degrees centigrade during evacuation in order to liberate gases occluded in the parts. Since the parts are in a vacuum and are usually surrounded by a glass bulb, induction heating is the ideal method. The heating coils are usually made to fit the bulbs and may be used either on stationary evacuation systems or on rotary systems. Other similar applications are "getter"-flashing and vacuum-firing systems. Still other applications are in sealing metal to glass, in brazing tube parts together, and in welding. In all of these applications the chief advantages are accurate control and speed of heating. The radio-frequency generators are usually of the vacuum-tube type operating at about 200 to 500 kilocycles. Units of about 2 to 15 kilowatts are used. The theory of heating is developed from simple air-cored transformer considerations and an example is given.

Introduction

INDUCTION heating is very widely used in the radio electron-tube industry. This has been true starting from the early 1920's. The main use has been in degassing the electrodes of radio tubes during evacuation of the tubes. In evacuating, or exhausting, any type of electron tube it is necessary not only to remove the air from the tube envelope, but also to remove, to a great extent, gases and vapors occluded in the internal tube parts so that they will not be liberated later during use of the tube. The higher the temperature to which these parts can be brought during the exhaust process, the more rapidly the undesired gases can be pumped out. The temperature is limited by such considerations as evaporation of the electrode materials, melting of parts, or melting of the glass envelope. The temperature range is roughly 500 to 1500 degrees centigrade, although higher temperatures may be used in the case of high-power tubes.

In the earliest days of the radio electron-tube industry, heating of tube electrodes was accomplished by lighting the filament so that it would emit electrons, and then applying voltage to the other electrodes so that they would be bombarded by electrons. Under these conditions, the heat dissipated in an electrode is simply the product of the applied voltage and the current to the electrode. This method is still used in many cases, but it has been largely supplanted by induction heating. The reason for this change is that it is inadvisable to require modern filaments and cathodes to emit heavy electron current while the vacuum in the tube is poor. Modern cathodes are usually of the barium-strontium, oxide-coated filament type or of the thoriated-tungsten type. Both of these types of cathodes are very efficient sources of electron emission, but they are also sensitive to gas bombardment or oxidation by oxidizing gases. It is, therefore, very desirable not to heat the cathodes to operating temperature during poor vacuum conditions such as would be present while electrodes are giving off gas and vapor. Induction heating is, consequently, an ideal method of heating the electrodes of tubes, because the cathode may remain unenergized while the electrodes are being degassed. In addition, induction heating may be controlled very easily. It is small wonder, therefore, that this type of heating is so widely used in the tube industry.

Applications

A number of typical induction-heating applications will be described. Application to tube exhausting has already been mentioned. There are two main types of such applications, the first to stationary exhausting positions and the second to automatic rotary machines. Fig. 1 shows a stationary application. Here a 500-watt

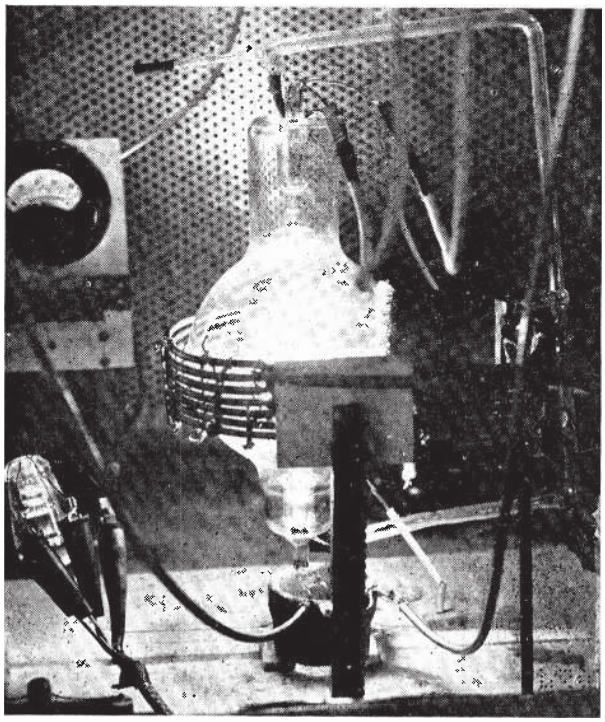

Fig. 1—Induction heating applied to radio tubes.

tube is being exhausted. The tube has been sealed to a glass exhaust manifold which leads to a vapor-diffusion pump. The anode of the tube, which is 2 inches (51 millimeters) in diameter and 3 inches (76 millimeters) long,

* Decimal classification: R590×R331. Original manuscript received by the Institute, June 25, 1945; revised manuscript received, August 22, 1945. Reprinted by permission from the *Transactions of the Electrochemical Society*, vol. 86, 1944.

† RCA Victor Division, Radio Corporation of America, Lancaster, Pennsylvania.

and made of tantalum sheet, is being heated to about 1300 degrees centigrade by the multiple-turn heating coil or inductor. The inductor is made of standard 0.25-inch (2.5-millimeter) copper tubing and carries a cur-

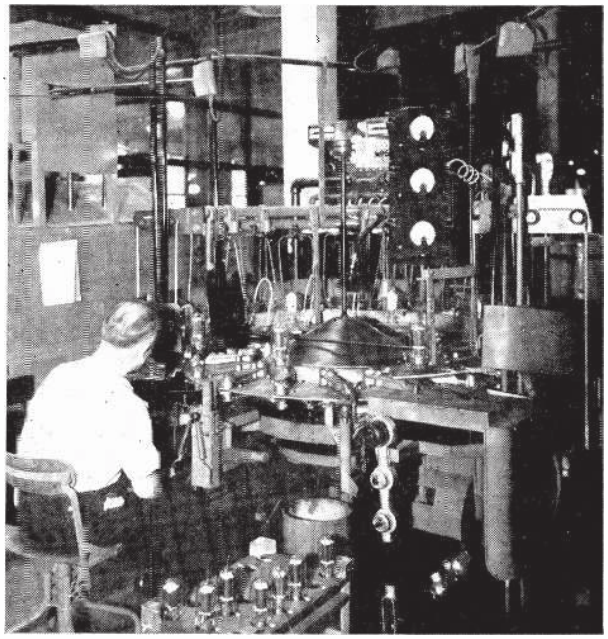

Fig. 2—Automatic rotary exhausting machine.

rent of about 150 amperes at about 300 kilocycles. This current is generated by an 8-kilowatt radio-frequency generator, which will be described later. The radio-frequency current is controlled by changing of voltage taps

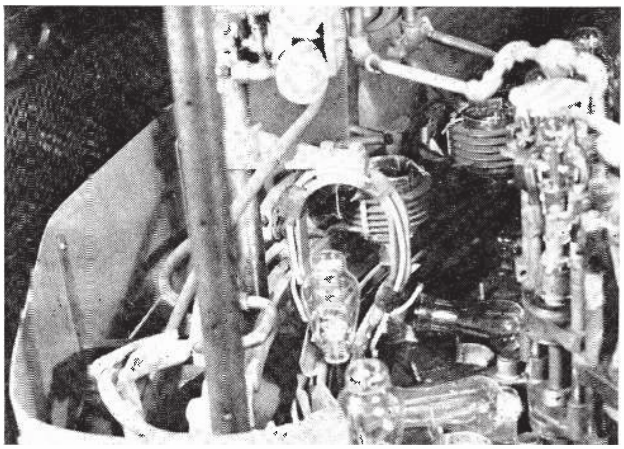

Fig. 3—Induction-heating position on rotary exhausting machine.

on the high-voltage-supply transformer and by variation of the filament voltage of the oscillator tubes in the generator.

Fig. 2 shows an automatic rotary exhausting machine. The exhaust tubing of the tubes is inserted into a rubber exhaust opening and connected by means of manifolds and a rotary valve to diffusion and mechanical pumps. The rotary table carrying the tubes turns at intervals which may be 0.1 to 3 minutes long. To the rear of the machine, the carbon anodes of the tubes may be seen heated to incandescence by high-frequency inductors. Just before the rotary table indexes, the inductors are raised up high enough to clear the tubes. Due to this arrangement, it is not necessary to have the inductors rotate. The radio-frequency generator may be seen in the left background; the heavily insulated leads carrying the current to the machine are in clear view. Several inductors are usually connected in series in order to utilize fully the capabilities of the generator.

Fig. 3 shows a closer view of the machine in Fig. 2. Fig. 4 shows a typical inductor held over a tube. The inductors shown in these two figures are made of flattened 0.5-inch (51-millimeter) diameter copper tubing through which cooling water is circulated. Inductor

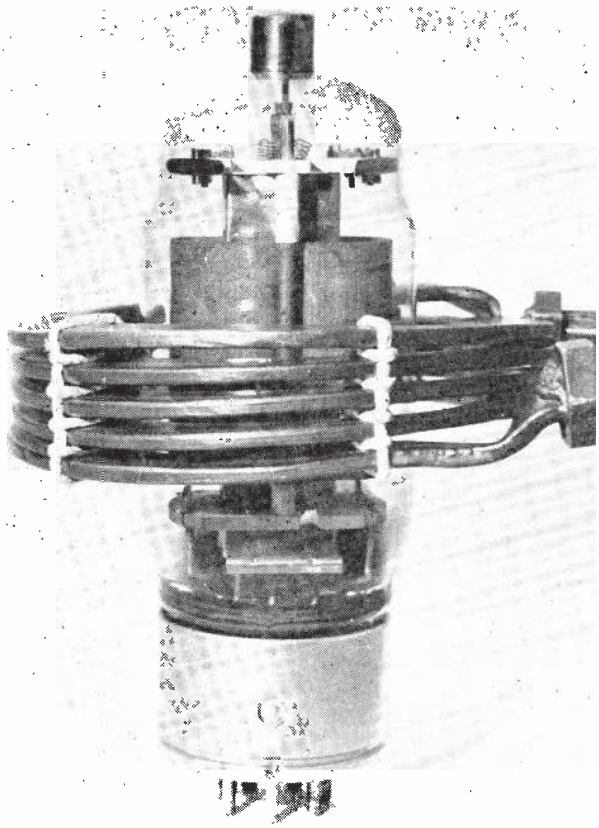

Fig. 4—Typical inductor and radio tube.

currents of 50 to 150 amperes are used; temperatures of 700 to 1200 degrees centigrade are commonly produced in the electrodes of the tubes being exhausted. The inductors are designed to be readily interchangeable by the use of standard pipe couplings. In this way, inductors of varying diameter and construction to suit the job at hand may be installed.

Fig. 5 shows an application of induction heating to vacuum firing. It is often desirable to heat tube parts to high temperature in good vacuum prior to assembly of the tubes. Occluded gases can be removed in this manner and it is also possible to remove vaporizable contaminating materials. In the particular case shown in Fig. 5, small tube parts are being vacuum-fired. Since these parts have very poor coupling to the inductor, they are placed in a box made of tantalum sheet. The induction currents heat the box which in turn heats the parts by

radiation and conduction. The box is supported within the long, 5-inch (127-millimeter) diameter glass bell jar, which rests on a rubber gasket lubricated with castor

Fig. 5—Induction-heated vacuum firing station.

oil. The vacuum pumps are mounted below the table. The inductor can be seen surrounding the bell jar. A multiple-turn inductor of 0.25-inch (6 millimeters) copper tubing is used; its power supply is a 16-kilowatt radio frequency generator.

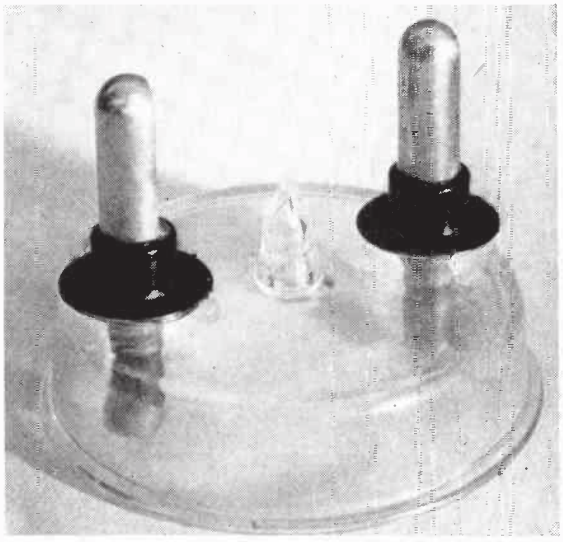

Fig. 6—Metal-to-glass seals made with induction heat.

Sealing Metal to Corning Glass

A considerably different application is sealing metal to glass. Fig. 6 shows a completed assembly consisting of a molded glass "dish" and two terminals of Kovar which have been sealed to the "dish." Kovar, an iron-nickel-cobalt alloy, has an expansion curve which closely matches that of Corning No. 705FN glass. As a result, butt glass-to-metal seals of the type shown are readily possible. To make a seal of this type the Kovar and glass can be heated by gas-oxygen flames, but much more uniform results are obtained by heating the Kovar by induction. Fig. 7 shows the setup used for making the

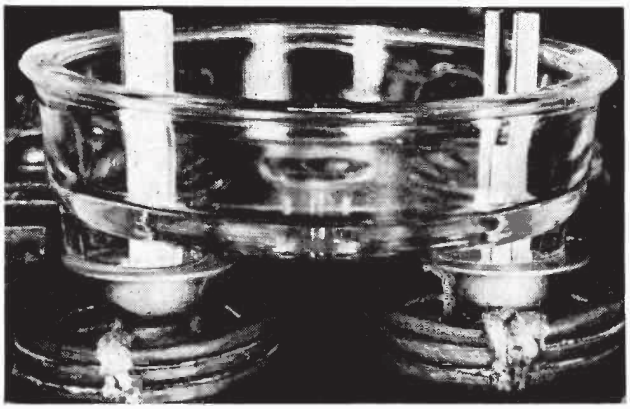

Fig. 7—Metal-to-glass sealing setup

seal just described. The glass dish and two terminals are held in position by suitable means. The two Kovar cups are heated by the small inductors. The glass dish

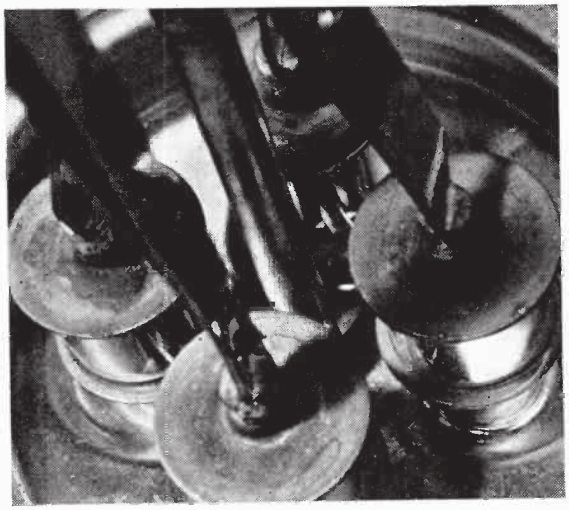

Fig. 8—Typical silver-soldered assembly.

may be moved up and down. The Kovar cups are heated until they oxidize slightly and then the glass dish is pressed down so that the two flat-ground openings in the dish contact the cups. Moderate pressure is applied while the cup heating is continued. In a short time the glass softens and flows. In this state it dissolves the surface oxide on the cups, and an intimate bond results. Heating is then stopped and the assembly is placed in a continuous annealing oven so as to remove any strains introduced in the glass. The entire sealing operation requires only about one minute. An 8-kilowatt vacuum-tube radio-frequency generator is used. This method, which has been in use about 5 years with women

operators, has been singularly free of difficulties although the operation itself was once regarded as a job requiring many years of training.

Brazing

Still another application of induction heating is in brazing. Fig. 8 shows a typical case. The large flange is made of Kovar and four Kovar glass assemblies are brazed to the flange using Handy and Harman "BT" silver solder. The joint must be vacuum-tight. The flange is mounted, as shown in Fig. 9, over a 5-turn

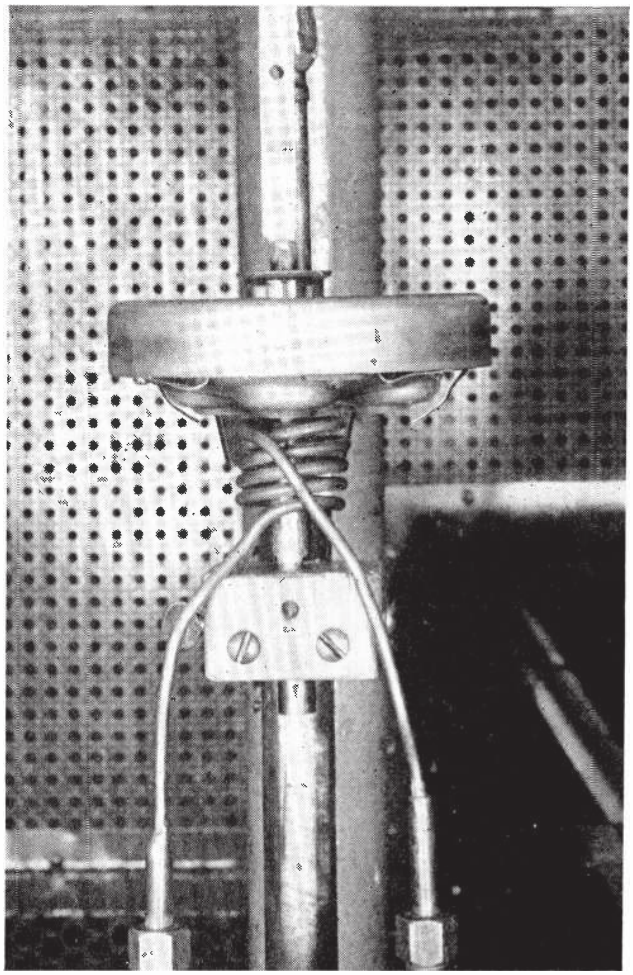

Fig. 9—Silver-soldering setup.

inductor. A single turn of wire solder is placed around the joint to be brazed. A bell jar fed with hydrogen from the top is placed over the work. The radio-frequency generator is then turned on until the silver flows as observed through a window. Since the heating is done in a reducing atmosphere, all metal parts stay bright. An 8-kilowatt furnace is used, although a smaller one would be satisfactory. Experience has shown that soldering of Kovar is much more satisfactory when done this way. Furnace soldering, where the parts are held above the soldering temperature for several minutes, and then cooled slowly, often gives difficulty because the solder can enter grain boundaries in the Kovar and split it open. For certain sizes and shapes, induction soldering may be effected with sufficient speed and the heat so localized that splitting does not occur.

Radio-Frequency Generators

Fig. 10 shows a typical 8-kilowatt radio-frequency generator as used in manufacturing operations. These generators use two Type 892 water-cooled triodes. These

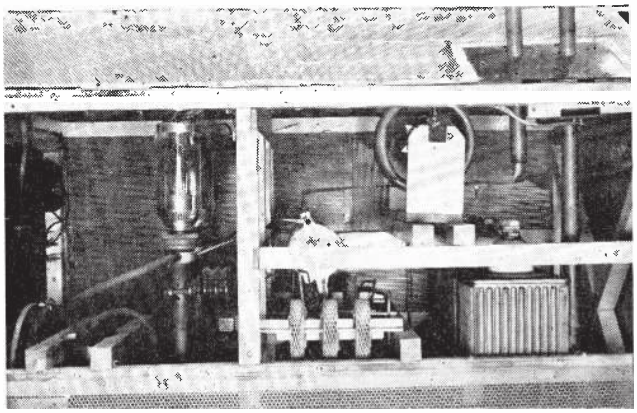

Fig. 10—Eight-kilowatt radio-frequency generator.

tubes have tungsten filaments and are rated for operation as oscillators with a direct-current power input of 30 kilowatts at 15 kilovolts and 2 amperes. The anodes are rated to dissipate up to 10 kilowatts.

Fig. 11 is a simplified circuit diagram of the above generator. In this generator the tubes are operated with 60-cycle alternating-current plate voltage in order to simplify the design of the generator. (When it is desired to utilize the full capability of the oscillator tubes, they are operated with direct-current rather than with alternating-current plate voltage.) Since the oscillator tubes

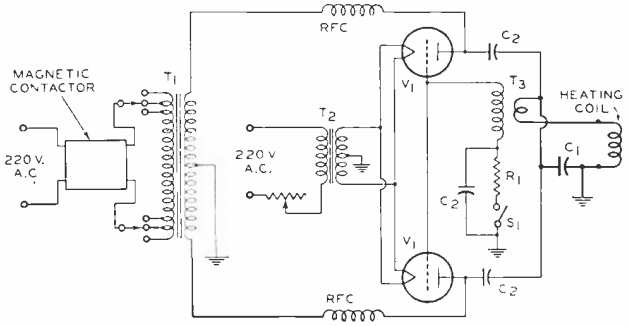

Fig. 11—Eight-kilowatt radio-frequency generator circuit.
Range = 250 to 400 kilocycles.
V_1 = RCA-892 water-cooled power tube
T_1 = 12.5-kilovolt power transformer. Total secondary voltage 7 to 18 kilovolts
T_2 = filament transformer
T_3 = feedback transformer
RFC = radio-frequency choke coil
C_1 = mica capacitor, 0.014 to 0.021 microfarad, 140 to 210 amperes
C_2 = mica capacitor, 0.004 microfarad
R_1 = grid-bias resistor, 1000 to 6000 ohms
S_1 = output control switch

themselves act as rectifiers of the 60-cycle power, it is necessary to use two tubes, operating on opposite secondary-winding terminals of a 60-cycle transformer with the center tap of the secondary grounded. Thus,

one oscillator tube operates on one-half cycle and the other on the other one-half cycle. The rectified currents supplied by the tubes buck each other and there is, therefore, no direct-current flux produced in the transformer.

The Type 892 tubes are effectively connected in parallel for radio-frequency currents by means of mica capacitors. The radio-frequency circuit consists partly of a bank of mica capacitors of 0.014- to 0.021-microfarad capacitance and rated to carry 140 amperes to 210 amperes at 300 kilocycles, and partly of a parallel inductance composed of the external inductors and leads, and an internal coil which couples to a second coil for feedback of excitation voltage to the grids of the Type 892 tubes.

Control of output current is obtained by means of taps on the primary of the plate-supply transformer and by means of a filament voltage control. The latter gives fine control by varying the electron emission of the Type 892 filaments. The generator is equipped with a filament voltmeter, plate-current meter, and a radio-frequency output-current meter.

Since the Type 892 tubes are water-cooled, a water-flow meter and interlock are provided so that the generator is shut off automatically if the water flow drops below a safe value. A plate-current overload relay is also provided.

The generator is turned on and off when in service by opening the grid-leak resistor. This method very effectively cuts off the generator and, since the current in the grid resistor is only a few hundred milliamperes, no unusual relay is needed. Generators of this type have proved very reliable and flexible.

Theory of Induction Heating

Many cases of induction heating in the radio industry concern thin-walled cylinders. In other cases, the depth of penetration of the current is so small that the load can be considered a thin-walled cylinder, with the wall thickness equal to the depth of penetration. The inductor and the load can thus be considered as an air-cored transformer. The mathematical solution of this heating problem is very simple.[1,2,3] The expression for the efficiency of heating is

$$n = \frac{1}{1 + \frac{1}{K^2}\left(\frac{1 + Q_2^2}{Q_2 Q_1}\right)} \tag{1}$$

where K = coefficient of coupling between inductor and the load
$Q_1 = Q$ of the inductor
$Q_2 = Q$ of the load.

Q is defined as the ratio of reactance of a circuit element to the series resistance of the element.

In the case of an inductance L having a resistance R at a frequency of f,

$$Q = \frac{2\pi fL}{R} = \frac{\omega L}{R}.$$

A study of (1) shows that efficiency increases with Q_2 and is essentially at its maximum value when $Q_2 = 3$.

Further, the current required in the inductor to produce W watts in the load is

$$I = \frac{\sqrt{W}}{K\sqrt{\omega L_1}}\sqrt{\frac{1 + Q_2^2}{Q_2}} \tag{2}$$

where L_1 = unloaded inductance of the inductor.

The voltage across the inductor is

$$E \cong I\omega L_1\left(1 - K_2\frac{Q_2^2}{1 + Q_2^2}\right). \tag{3}$$

In the application of the above equations, practical units are to be inserted; i.e., henries, ohms, watts, root-mean-square volts and amperes, and cycles per second.

The question now arises, how are these quantities to be determined? If both the inductor and load are coaxial cylinders, the inductance of each and also their mutual inductance may be calculated.[4] The coupling coefficient is then the mutual inductance divided by the square root of the product of the two individual inductances. The reactance of the load can be calculated at the operating frequency. The resistance around the periphery of the load can also be easily calculated. If the thickness of the wall of the load is greater than the depth of penetration of the current, the thickness should be taken as equal to the depth of penetration. The Q of the load and the reactance ωL_1 of the inductor are next calculated. Thus, all constants for (2) and (3) are known, and with further insertion of the watts desired in the load, both inductor current and voltage may be obtained. Since it may not be practical to calculate the Q of the inductor very reliably, measurement may be necessary if determination of efficiency is desired.

If neither the inductor nor the load possesses geometrical shapes for which there are formulas for inductance and mutual inductance, measurement can be made. A Boonton Model 160-A Q meter is very convenient for this purpose. First, a model of the inductor is made of the same length and cross section and wound with enough turns of wire to bring the inductance up to 600 to 1000 microhenries so as to permit obtaining resonance with the variable Q meter capacitance of 450 micromicrofarads. The Q meter is resonated at the desired frequency and a reading of Q and the required resonant capacitance are noted. This permits calculation

[1] W. Esmarch, "Zur Theorie der kernlosen Induktionsöfen," *Wiss. Veröffent. Siemens-Konzern*, vol. 10, pp. 172–196; 1931.
[2] H. B. Dwight and M. M. Bagai, "Calculations for coreless induction furnaces," *Elec. Eng.*, vol. 54, pp. 312–315; March, 1935.
[3] G. H. Brown, "Efficiency of induction heating coils," *Electronics*, vol. 17, pp. 124–129, 382–385; August, 1944.
[4] Bureau of Standards Circular No. 74, Radio Instruments and Measurements, 1938.

of L_M, ωL_M, and R_M, where the subscript M refers to the model. The load is then inserted. (If the load is magnetic at room temperature, but not at the desired temperature, an identical load of nonmagnetic metal should be used.) The Q meter is reresonated and the new values of Q and capacitance are noted. Again L_M', $\omega L_M'$, and R_M' are calculated. The original values are subtracted giving $\Delta\omega L_M$ and ΔR_M. The theory shows that

$$\frac{\Delta\omega L_M}{\omega L_M} = K^2 \frac{Q_M^2}{1 + Q_M^2} \tag{4}$$

and that

$$Q_M = \frac{\Delta\omega L_M}{\Delta R_M}. \tag{5}$$

Equation (5) gives Q_M which is inserted in (4). Equation (4) can be solved for the coupling coefficient K. Knowing the resistivity of the actual load at the desired temperature and the resistivity of the load used during the test above, we find that the true Q of the load is

$$Q_2 = Q_M \sqrt{\frac{\rho_M}{\rho_2}} \tag{6}$$

where ρ_M is the model load resistivity and ρ_2 the actual load resistivity. Equation (6) assumes that the depth of penetration is less than about one fifth of the radius of the load. Finally, the measured ωL_M must be reduced by the ratio of the square of the inductor turns to the square of the model turns, so as to get the true inductor reactance ωL_1. All values are then known for (2) and (3).

Both of the above methods have been used with good results. One example will be given. The load and inductor were those shown in Fig. 4. A model of the inductor was made by winding 91 turns on a coil form. The model had the same length as the inductor, but the diameter was 3.75 inches (95 millimeters) instead of 3.5 inches (89 millimeters). This requires a later correction in K. The model connected to a Boonton Q meter, gave at 300 kilocycles a Q of 180 and a resonant capacitance of 272 micromicrofarads. By a second measurement at 600 kilocycles, it was found that the model had 7 micromicrofarads stray capacitance. Therefore the corrected capacitance was 279 micromicrofarads. From the usual formula connecting L, C, and f, the inductance of the model was 1010 microhenries and its reactance was 1905 ohms at 300 kilocycles. Thus the model had a resistance of $1905/180 = 10.6$ ohms.

Next, the anode of Type 813 tube was inserted in the model and it was found that at 300 kilocycles the Q was 29 and the resonant capacitance was 286 micromicrofarads. Repeating the calculations above the new model reactance was 1810 ohms and the new resistance was $1810/29 = 62.4$ ohms. The change in reactance was, thus, $1905 - 1810 = 95$ ohms, and the change in resistance was $62.4 - 10.6 = 51.8$ ohms. Applying (5) we find that

$$Q_M = \frac{95}{51.8} = 1.83.$$

In this case, since an actual anode and not a model was used, $Q_M = Q_2$. However, the anode was not at operating temperature, so the correction of (6) is still necessary. The ratio of hot-to-cold resistance in this case was 0.85. Therefore the hot

$$Q_2 = 1.83\sqrt{\frac{1}{0.85}} = 1.99.$$

Applying (4), we obtain

$$\frac{95}{1905} = K^2 \cdot \frac{1.83^2}{1 + 1.83^2}.$$

From this equation

$$K = 0.25.$$

This value needs revision, due to the fact that the inductor model had too large a diameter. As an approximation, K is inversely proportional to diameter. Thus the corrected K became

$$0.25 \times \frac{3.75}{3.5} = 0.268.$$

The reactance of the model inductor was then reduced by the square of the number of turns in order to get the reactance ωL_1 of the actual inductor, which had 4.5 turns. We obtain

$$\omega L_1 = 1905 \times \left(\frac{4.5}{91}\right)^2 = 4.63 \text{ ohms}.$$

The power required in the anode was calculated by assuming that the temperature was 1100 degrees centigrade and the radiation coefficient was 0.8, and by allowing 5 per cent for end effects. This gave 1200 watts.

Now applying (2) and (3), we obtain

$$I = \frac{1}{0.268}\sqrt{\frac{1200(1 + 1.99^2)}{4.63 \times 1.99}} = 95 \text{ amperes}$$

and

$$E = 95 \times 4.63\left(1 - \frac{1}{0.268^2} \cdot \frac{1.99^2}{1 + 1.99^2}\right) = 415 \text{ volts}.$$

Actual measurements on an exhausting machine gave $I = 87$ amperes, $E = 365$ volts at a frequency of 308 kilocycles and with an anode temperature of 1100 degrees centigrade. This comparison shows that satisfactory results can be obtained by this method.

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Fine Wires in the Electron-Tube Industry*

GEORGE A. ESPERSEN†, ASSOCIATE, I.R.E.

Summary—This article discusses primarily the application of fine wires in the electron-tube industry. Some fundamental basic properties which confront the wire manufacturer are briefly discussed. Design formulas, including a nomograph, are given for electron-tube filaments. The use of platings of gold, platinum, and zirconium on metals of the refractory group have assisted in the reduction of grid emission. A unique method of utilizing zirconium, both to accelerate the vacuum exhaust process and to serve as a continuous "getter," is described. A novel method of securing a uniform rate of evaporation of thin films of metals is discussed.

Methods of Specifying Characteristics

FINE WIRES such as nickel, nickel alloys, tungsten, thoriated tungsten, molybdenum, and tantalum have been used by the electron-tube industry from the date of its inception. The practices set up for manufacturing incandescent-lamp filaments were readily applied to filaments, heaters, and grids for electron tubes. Through a period of years, various standards for wire quality and characteristics have been established independently by individual electron-tube manufacturing companies. These standards in most cases are practically identical, with minor deviations occurring where certain other fabricating processes are to be considered.

The basic properties which have been considered are: (1) finish; (2) weight; (3) diameter; (4) elongation; (5) tensile strength; (6) straightness; (7) electrical resistance; (8) chemical composition; (9) brittleness.

The finish of a wire may vary from a clean, shiny surface to a dark matt surface. Manufacturing specifications may also include such statements as freedom from kinks, waves, cracks, slivers, seams, burrs, roughness, soap drawing compounds, oil, foreign matter, and oxides.

The weight of the fine wires is usually expressed in milligrams per 200 millimeters. Tolerances on weight usually vary from plus or minus 2 per cent for filaments to plus or minus 4 per cent for grid wires, these values depending upon the degree of control required to maintain the specified characteristic tolerances.

The diameter of the wire is usually specified as a nominal value for fine wires, and it can readily be computed by using either of the following formulas:

$$D = K_1\sqrt{W} \tag{1}$$

$$W = K_2D^2 \tag{2}$$

where D = the mean diameter of the wire in mils
W = the weight of the wire in milligrams per 200 millimeters of length
K_1 and K_2 = constants depending upon the densities of the wire.

Table I indicates values for K_1 and K_2 for the materials named.

TABLE I

Material	K_1	K_2
Molybdenum	0.989	1.022
Tungsten	0.717	1.950
Tantalum	0.771	1.682
Thoriated Tungsten	0.725	1.903
Nickel	1.055	0.898
Magno Nickel	1.064	0.883

The diameter of a wire is usually checked by the wire manufacturer for any out-of-round tendencies, which usually indicate excessive die wear and serve as a warning to change defective dies. Lack of uniform diameter may cause localized bright spots, if the wire is used as a filament, which would tend to shorten its useful life; if utilized as a grid, no detrimental effects should be observed providing the specified weight tolerance is maintained.

Out-of-roundness is usually expressed as a percentage equal to

$$\frac{A - B}{A} \times 100$$

where A = the maximum diameter of the cross section in inches, and
B = the minimum diameter of the cross section in inches.

The elongation of fine wires is usually specified if this material is to be used for grid material, in particular for grids requiring stretching of the laterals to maintain a specified shape. Typical values of elongation range from 17 to 22 per cent.

The straightness is usually specified for grid lateral material and tungsten heaters of the spiral type. This quality indicates the relative freedom from strain resulting from proper annealing of the wire. No standard method of testing this characteristic has been established in the electron-tube industry.[1] The usual crude test is to suspend a three-foot length at the ends in a horizontal plane approximately twenty inches apart and observe that the sample assumes the shape of a catenary free from bulges or irregular rises or twists.

Brittleness tests are specified for tungsten wire, which is used either as direct or indirect heaters. Stringent

* Decimal classification: R331×R282.1. Original manuscript received by the Institute, June 22, 1945; revised manuscript received, October 10, 1945.

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[1] See "American Society for Testing Materials Standards Handbook," 1944, p. 1794.

vibration testing of tubes has made such tests imperative. Manufacturers of electron tubes differ only in detail as to how this quality is measured. The usual procedure consists of supporting one end horizontally by clamping and bending the wire downward to a specified angle at which value the specimen shall not break or show a tendency towards splitting.

Electrical-resistance and chemical-composition tests are usually established only as additional tests. These properties have usually been well adhered to by most wire manufacturers, since it is very difficult to have any undue quantities of volatile impurities at the temperatures at which wires of the refractory group are sintered. Manufacturers who make alloys consisting of two or more metals of the refractory group conduct thorough tests on electrical conductivity as well as the chemical composition. In cases where the heaters or filaments are formed in the shape of coils, either inductive, noninductive, flat pancake, or spiral, nonsag material is usually specified.

It is clear that if the tube engineer puts such rigid quality requirements on his wires, the wire manufacturers can supply a satisfactory product only if they are equipped with up-to-date wire-drawing and wire-plating machinery.

In addition, a scientific control system, using the latest apparatus handled by a skilled staff to check the finished product is necessary. These features can be provided only by wire manufacturers in intimate contact with the electron-tube manufacturers.

Fine wires employed as a base metal for emitters usually consist of pure nickel, aluminum nickel, cobalt nickel, silicon nickel, tungsten, thoriated tungsten, and nickel-plated tungsten. Wires containing nickel are base metals for oxide-coated filaments of the alkaline earth group, usually barium, strontium, and calcium. Tungsten wires have been utilized either as a base metal for indirectly heated cathode-type tubes or as a direct emitter for high-power water-cooled copper-anode tubes. Thoriated-tungsten wire has been successfully employed as a direct emitter for power-transmitter tubes where the maximum plate dissipation does not exceed 1000 watts or the maximum plate voltage does not exceed 4000 volts. Nickel-plated tungsten wires having

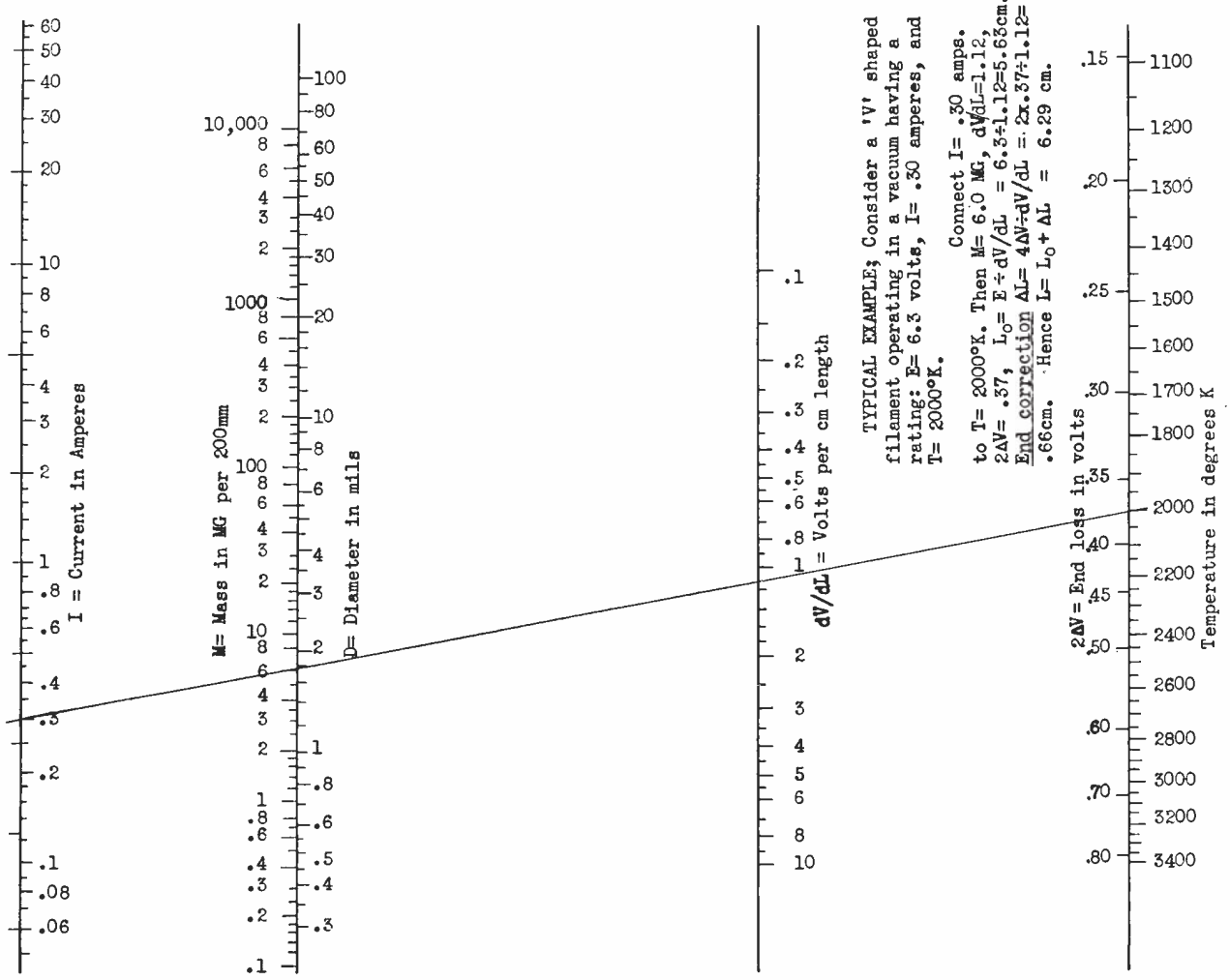
I = Current in Amperes
M= Mass in MG per 200mm
D= Diameter in mils
dV/dL = Volts per cm length
2ΔV= End loss in volts
Temperature in degrees K
TYPICAL EXAMPLE; Consider a 'V' shaped filament operating in a vacuum having a rating: E= 6.3 volts, I= .30 amperes, and T= 2000°K.
Connect I= .30 amps. to T= 2000°K. Then M= 6.0 MG, dV/dL=1.12, 2ΔV= .37, L0= E÷dV/dL = 6.3÷1.12=5.63cm. End correction ΔL= 4ΔV÷dV/dL = 2x.37÷1.12= .66cm. Hence L= L0 + ΔL = 6.29 cm.

Fig. 1—Nomograph for design of tungsten filaments. (See footnote reference 2.)

diameters of less than 0.001 inch are suitable as a base metal for oxide-coated filaments of the alkaline earth group on minature and hearing-aid-type tubes.

Design Fundamentals

The following formula is generally employed by electron-tube engineers in the design of filaments. (End losses are not considered.)

$$R_h = \frac{2\rho L_h d}{W_h}$$

where R_h = heater resistance at operating temperature expressed in ohms
ρ = specific resistance in ohms at the operating diameter
d = density of the heater material in milligrams per cubic centimeter
W_h = heater-wire weight in milligrams per 200 millimeters of length
L_h = heater-wire length in millimeters.

Fig. 1 takes into consideration the correction factor for end losses due to conduction to the leads to which the filament is welded and the contact with the filament tension hook.[2]

Grid Emission

Grids on most receiving tubes and a number of transmitting types use lateral wires having diameters of less than 0.010 inch. The most common materials being used are manganese-nickel, nickel-chromium-iron alloys, tantalum, molybdenum, molybdenum-iron alloys, zirconium-clad molybdenum, platinum-clad molybdenum, and gold-plated molybdenum.

To reduce grid emission, manganese-nickel material has been utilized on most receiving-type tubes while zirconium-clad molybdenum, platinum-clad molybdenum, and gold-plated molybdenum have been used on most transmitter-type tubes.

To date, a controversy still exists as to whether platinum-clad molybdenum is superior to gold-plated molybdenum for the prevention of grid emission. Both materials are being used successfully, and data should be available in the near future as to which displays superior qualities. However, the use of platinum is recommended when either the degassing or operating temperature during processing is above or dangerously close to the melting point of gold. The gold-plating of molybdenum wire in a continuous process to provide a well-adherent nonporous coating offers certain fabricating difficulties which have now been overcome.

To date, it has been virtually impossible for the wire manufacturer to obtain the same results with plating of platinum as with gold, hence we must resort to a mechanical cladding process to produce platinum-clad molybdenum. From the stand of the wire manufacturer, plating is a simpler process than applying a platinum tube to a molybdenum core prior to the drawing operation.

The application of grid-emission inhibiting wires has found usage in grids (Fig. 2) of close-spaced triodes, pentodes, and velocity-modulated tubes where spacings from the cathode to the grid may range from 0.004 inch to 0.015 inch. The relative merits of zirconium-clad molybdenum for the prevention of grid emission has been explored on a number of medium-power high-frequency pentodes.

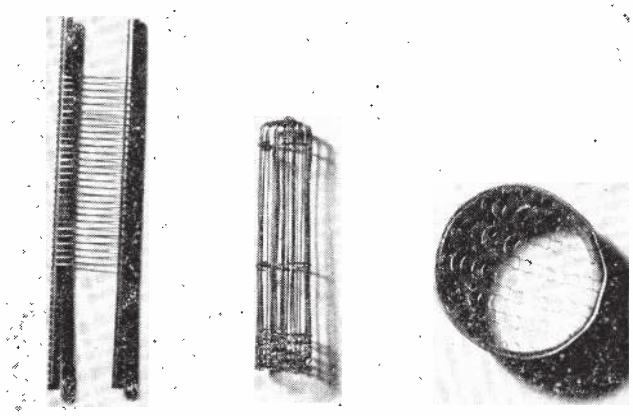

Fig. 2—Grid assemblies of various designs.

Electron-tube manufacturers who specialize in miniature or acorn-type tubes have usually had difficulties with molybdenum wire on grids due to heavy oxidation resulting from the heat generated during the sealing operations. Where possible, inert gases have been introduced into the envelope to reduce the degree of oxidation, but this method has not been entirely satisfactory. Molybdenum oxide on the grid laterals has a tendency to poison the emitting cathode, particularly if it consists of the alkaline earth type. Gold and silver plating of the molybdenum wire, prior to grid making, has offered considerable relief in reducing the degree of oxidation. Platinum and zirconium cladding have also been highly successful in this respect.

Getter Wires of Zirconium

The use of fine zirconium wire as a getter material has had numerous applications in X-ray tubes where the barium getter has proven to be unsatisfactory due to its higher vapor pressure at the operating temperature of the tube. Zirconium has the peculiar property of absorption of hydrogen at temperatures ranging from 300 to 400 degrees centigrade, and absorption of all other gases (excepting rare gases) at temperatures ranging from 1000 to 1600 degrees centigrade.

Zirconium wire which is unsupported is not sufficiently strong to maintain its preformed shape at a

[2] W. E. Forsythe and A. G. Worthing, "The properties of tungsten and the characteristics of tungsten lamps," *Astrophys. Jour.*, vol. 61, pp. 146-185; 1925.

temperature of 1600 degrees centigrade.[3] It has been found desirable to support it by winding zirconium wire (0.005 inch in diameter) alongside a tungsten wire (0.007 inch in diameter) on a tungsten or molybdenum core that is 0.008 inch in diameter. Zirconium wire exposed to the atmosphere has a tendency to oxidize slightly on the surface. This oxidation does not seriously impair the gettering qualities since it can be removed by glowing at 1600 degrees centigrade in a vacuum of approximately 1×10^{-6} millimeter of mercury. The combination zirconium-tungsten assembly wound on a molybdenum core has the advantage of serving as a support

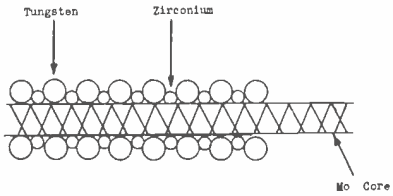

Fig. 3—Sketch showing cross section of a zirconium getter assembly.

for the rather weak zirconium and also makes possible glowing of the assembly at a temperature slightly higher than the melting point of zirconium, so a zirconium mirror can be formed on the glass retainer envelope.

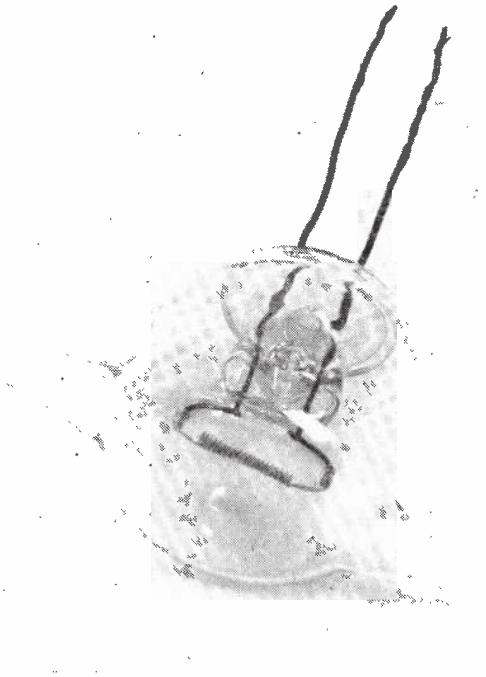

Fig. 4—View of helical coil sealed in glass envelope.

This assembly has the advantage that it prevents the liquid zirconium from forming globules about the core wire, since it is retained between two tungsten wires which serve as a trough preventing the zirconium from flowing along the length of the wire.

[3] See United States Patent No. 2,336,138. A. J. van Hoorn and G. Thurmer, "Vaporization of metals," December 7, 1943.

Fig. 3 shows a cross section of a zirconium getter assembly. To obtain continuous gettering action in a tube, it is suggested that the getter assembly be assembled either in series or parallel with the tube filaments.

Test runs using assemblies as indicated in Fig. 4 were employed to accelerate the vacuum exhausting process. This assembly is inserted between the diffusion pump and the tube to be exhausted. Prior to exhausting a given tube, the getter coil is glowed at 1650 to 1700 degrees centigrade for approximately one minute. The

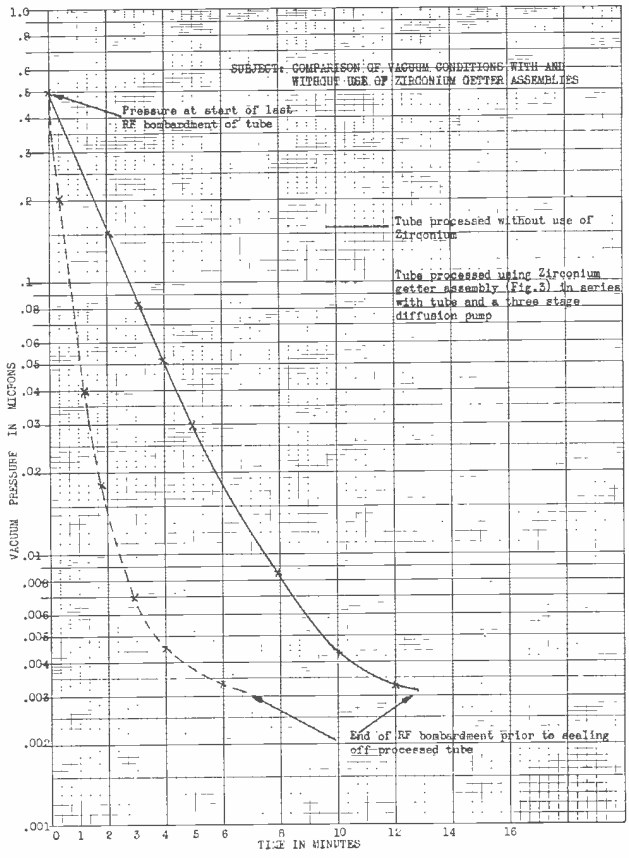
SUBJECT: COMPARISON OF VACUUM CONDITIONS WITH AND WITHOUT USE OF ZIRCONIUM GETTER ASSEMBLIES
Pressure at start of last RF bombardment of tube
Tube processed without use of Zirconium
Tube processed using Zirconium getter assembly (Fig.3) in series with tube and a three stage diffusion pump
End of RF bombardment prior to sealing off processed tube
VACUUM PRESSURE IN MICRONS
TIME IN MINUTES

Fig. 5—Curves showing comparison of vacuum conditions with and without the use of zirconium getter assemblies.

tube is exhausted in a normal manner, out-gassing the metal parts at a high frequency and internally bombarding the elements as required. When the vacuum approaches 1.0×10^{-3} millimeter of mercury, the getter coils are heated slowly to a temperature of 1650 degrees centigrade and maintained at this temperature for approximately five minutes. At the end of this period the vacuum pressure ranged from 1.0×10^{-5} to 1.0×10^{-6} millimeter of mercury. The time of pumping schedule of electron tubes exhausted with the use of zirconium getter coils was reduced approximately 25 per cent depending upon the type of tube (Fig. 5).

The zirconium getter coil can be used repeatedly for gettering until the coil fails mechanically. The author has utilized a single coil as many as fifty times without noticing any impairment of the gettering qualities.

Wires for Evaporating Metals in Vacuums

The evaporation of metals has been successfully effected through a design of coil similar to the one shown in Fig. 6. Evaporation of thin films of silver, copper, gold, aluminum, etc., on glass, quartz, mica, etc. has

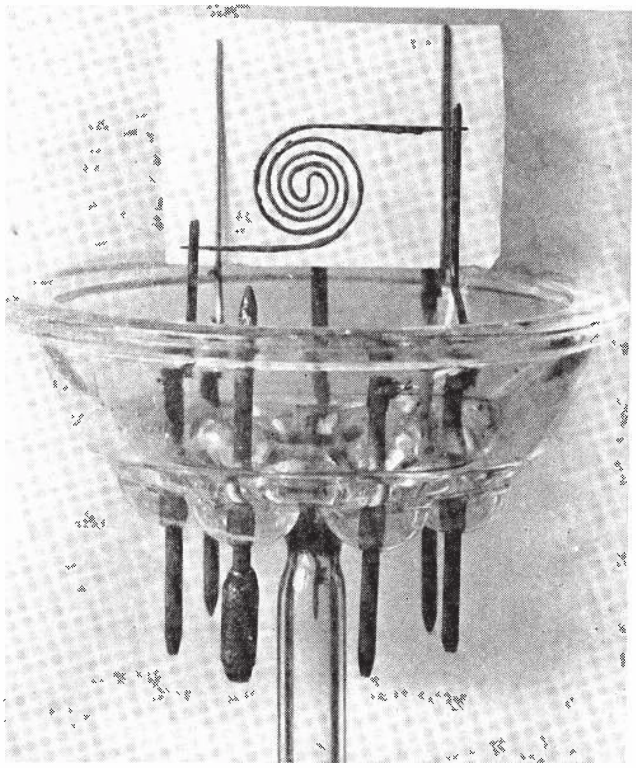

Fig. 6—View of evaporating coil.

been accomplished by replacing the zirconium (Fig. 3) with the metal to be evaporated. This type of assembly insures a uniform rate of evaporation and reduces the tendency of the evaporating metal towards forming globules, which result in an uneven diameter causing localized spheres of evaporation. Evaporation of silver, aluminum, copper, gold, etc., with the pancake-type coil (Fig. 6) which had a center-core rod of molybdenum was carried out at a pressure of 10^{-3} millimeter of mercury.

The intimate contact of the plating wire in the coiled coil assembly made possible uniformity of control of evaporation. All assemblies using the same type of plating wire evaporated at approximately the same glow current would plate at the same rate. Measurements on a number of mica plates indicated that the weight of the evaporated material did not deviate by more than five per cent on approximately 100 specimens. Using fine wires rather than heavy wires in the order of 0.025 inch in diameter insured a minimum heating of the specimen to be plated, thus preventing a chemical breakdown of the sample as well as insuring a cool surface for the sample, which also resulted in a plating free from oxides, bubbles, and peeling. It was observed that the more rapid the plating process the better was the quality of the plating.

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A Three-Beam Oscillograph for Recording at Frequencies up to 10,000 Megacycles*

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Summary—**A fundamental limiting factor in the application of high-speed cathode-ray oscillographs to the recording of high-frequency voltages or fast transients has been the error introduced by the finite time required for an electron to traverse the deflecting fields. A description is given of a three-beam high-speed micro-oscillograph which extends the range of application of single-sweep oscillographic recording by a factor of approximately 10 in frequency over previous limits imposed by transit-time distortion. The reduction in deflection sensitivity attributable to transit-time effect is calculated to be 4 per cent at 3000 megacycles and 40 per cent at 10,000 megacycles. Single-sweep oscillograms of 3000 and 10,000-megacycle oscillations and breakdown transients with fronts on the order of 10^{-9} second duration are shown.**

Introduction

Nature and Importance of Transit-Time Distortion

UNTIL recently limitations in the application of oscillographic techniques imposed by transit-time distortion have caused but little concern because there was seldom occasion to use or study frequencies so high or transients so fast that the effect was of great consequence. However, the rapid growth of the microwave art and its very important applications made

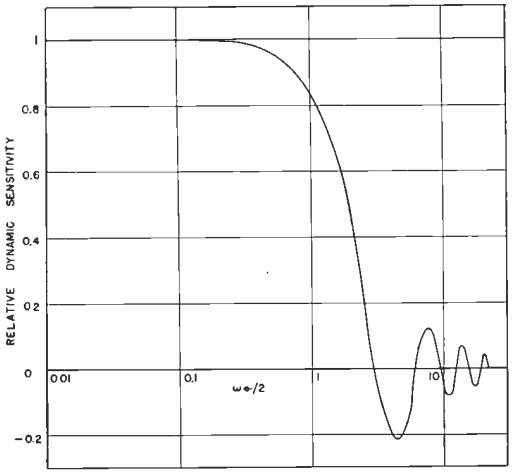

Fig. 1—Effect of electron transit time on sensitivity.

the development of an oscillograph for single-trace recording in the microwave region a matter of considerable importance. It was also realized that such an instrument would be exceedingly useful for fundamental studies on dielectric breakdown.

Considering an oscillograph with parallel electrostatic deflecting plates, it is well known that the decrease in sensitivity at high frequencies due to transit-time effect is given by

$$\text{relative dynamic sensitivity} = \frac{\sin \omega\theta/2}{\omega\theta/2} \qquad (1)$$

where ω is the angular frequency of the deflecting voltage and θ is the time taken for the electron to pass between the plates.[1] This formula neglects the action of the stray field at the ends of the deflecting plates, but it is sufficiently accurate for most purposes, particularly if a somewhat longer effective plate length is used in calculating θ. The variation in sensitivity with increasing values of $\omega\theta/2$ is shown in Fig. 1.

If a pure sine wave, the period of which is comparable in magnitude to the transit time, is impressed upon the deflecting plates, a reduction in sensitivity is the only undesirable result. As long as sufficient sensitivity remains for a particular application, this gives little cause for concern. However, if a complex voltage containing components of sufficiently high frequency is to be studied, distortion will occur since the sensitivity will vary with each harmonic, and for harmonics in certain regions a relative phase shift of 180 degrees will appear.

In applying an oscillograph to transient problems, the distortion to be expected in reproducing an exponential

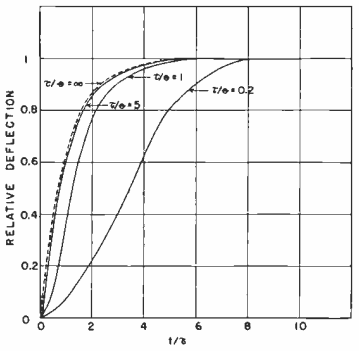

Fig. 2—Transit-time distortion in the recording of exponential fronts.

voltage front of the form

$$E(t) = E(1 - \epsilon^{-t/\tau}) \qquad (2)$$

is frequently a good criterion of the instrument's usability.[2] The nature of this distortion is best shown graphically as in Fig. 2. It will be seen that the ratio of the voltage time constant τ to electron transit time θ should have a minimum value of about 5 for accurate reproduction.

* Decimal classification: R388. Original manuscript received by the Institute, October 10, 1945. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 25, 1946.

† Formerly, Laboratory for Insulation Research, Massachusetts Institute of Technology, Cambridge, Massachusetts; now, Central Research Laboratories, Inc., Red Wing, Minnesota.

[1] H. E. Hollman, "Die Braunsche Rohre bei sehr hohen Frequenzen," *Hochfrequenz. und Elektroakustik*, vol. 40, pp. 97–103; September, 1932.

[2] Hans Klemperer and Otto Wollf, "Die Verzerrungen im Kathodenoszillographen bei hohen Messgeschwindigkeiten," *Arch. für Elektrotech.*, vol. 26, pp. 495–502; July, 1932.

Typical values of effective deflecting-plate length and accelerating voltage for a conventional high-speed oscillograph are 5 centimeters and 50 kilovolts respectively. For these constants the reduction in deflection sensitivity is 5 per cent at 500 megacycles, and in recording an exponential voltage, τ may have a minimum value of about 2×10^{-9}.

Where writing speed did not impose a lower limit, these values remained as approximate limits to the application of all high-speed oscillographs described in the literature up until 1939. The reason for this is that the upper frequency and lower time limits are, respectively, inversely and directly proportional to the transit time. The transit time in turn varies directly with the effective plate length and inversely with the square root of the electron-beam accelerating voltage. To decrease the effective plate length very much below 5 centimeters is not feasible in the conventional high-speed oscillograph for a number of reasons. One of these is that an already low voltage sensitivity would be decreased. Another is that the diameter of the electron beam demands a certain plate separation; hence, as the plate length is decreased, the stray field at the edge of the plates becomes more important, and little is gained. Increasing the accelerating voltage is a relatively fruitless proposition since the transit time varies inversely only as the square root of the voltage, which is already high, and furthermore, above 50 kilovolts the relativity correction for the electron velocity starts to become important so that even less is gained.

Principles and History of the Microoscillograph

In 1939, von Ardenne[3] presented an original idea on oscillograph design which seemed to offer good possibilities for developing an instrument which would extend considerably the range of oscillographic recording. His instrument, which he designates as a microoscillograph, is designed according to electron microoptical principles which he developed in his work on the electron-scan microscope. In the microoscillograph the writing spot is made very fine, on the order of 10^{-2} to 10^{-3} millimeter in diameter, and the entire oscillogram is reduced in size by a factor of 100 compared to normal-size records. To preserve detail, the record is of necessity made directly on the photographic emulsion, which must be inserted into the vacuum chamber. The record is examined through a low-power microscope, or a photographic enlargement of it may be made. The fine writing spot is obtained by imaging the effective electron source with a short-focal-length magnetic or electrostatic lens. As a result of reducing the scale of the beam and oscillogram, all the deflecting-plate dimensions may be decreased by a factor of 10 or more, which means a corresponding reduction in transit time of 10 or more.

Von Ardenne's oscillograph was not designed for the purpose of resolving ultra-high-frequency phenomena, however, so the reduction in transit time was only of incidental interest. Another result of the reduced scale employed in the microoscillograph is that the actual velocity of travel of the trace over the recording plane is small enough so that mechanical sweep methods, such as a rotating film drum, may be used to obtain reasonably small minimum resolving times. Von Ardenne was chiefly interested in this feature which enabled him to obtain oscillograms with a total duration of 0.4 second and a minimum resolvable time of 5×10^{-7} second. A 10-centimeter-diameter drum rotating at a little under 10,000 revolutions per minute was used to provide the linear sweep for this application.

The only worker who seems to have made any use of the low transit time afforded by the microoscillographic technique to permit oscillography in the microwave region is Hollmann.[4] His instrument, however, was designed for the analysis of steady-state high-frequency voltages by means of Lissajou figures, and with his design, in which a sealed-off tube and fluorescent screen is used, it is very doubtful whether either the writing speed or optical resolving power of the screen would be adequate to permit the photographing of single-trace oscillograms of very short duration.

In addition to the reduction in transit-time distortion, the microoscillograph possesses a number of other advantages over the conventional high-speed instrument. One of these is that the reduction in deflecting-plate size causes a corresponding reduction in capacitance and particularly distributed capacitance and stray capacitance to ground. This is clearly of considerable importance at ultra-high frequencies. Owing to the small dimensions and fine beam used in the microoscillograph, it is also considerably easier to design and construct a multiple-beam microoscillograph than a multiple-beam instrument of the conventional type. The advantages of a multiple-beam instrument are quite obvious. In transient research, the recording of simultaneous current, voltage, and timing waves is a common requirement. In von Ardenne's original instrument, two beams were obtained from a single electron source by a relatively simple twin aperture and magnetic focusing system. A later design using electrostatic focusing provided for recording six traces simultaneously on a rotating drum.[5] Another advantage of the microtechnique is that a large amount of information in the form of an oscillogram can be contained in a very small area. A complete oscillogram of usual proportions need occupy an area of but a few square millimeters. This means that a large number of records can be made on a small photographic plate. This last advantage is somewhat offset, of course, by the necessity for examining the records with a microscope, microprojector, or making photographic enlargements.

[3] M. von Ardenne, "Der Elektronen-Mikrooscillograph," *Hochfrequenz. und Elektroakustik*, vol. 54, pp. 181–188; December, 1939.

[4] H. E. Hollmann, "Ultra-high-frequency oscillography," Proc. I.R.E., vol. 28, pp. 213–220; May, 1940.

[5] M. von Ardenne, "A six-trace cathode-ray micro-oscillograph," (abstract) *Wireless Eng.*, vol. 19, p. 231; May, 1942.

With these facts in mind, a three-beam microoscillograph for recording single-trace oscillograms of low transit-time distortion at ultra-high frequencies was developed.

Construction Details

An assembly drawing of the completed mechanical design of the oscillograph proper is shown in Fig. 3. The entire assembly is designed to be easily demountable for adjustment and experimentation. Vacuum-tight connections between the various sections are made by tongue-and-groove flange joints using $\frac{1}{16}$-inch-thick neoprene as a gasket material. Where allowance for slight variations in alignment must be made, such as in

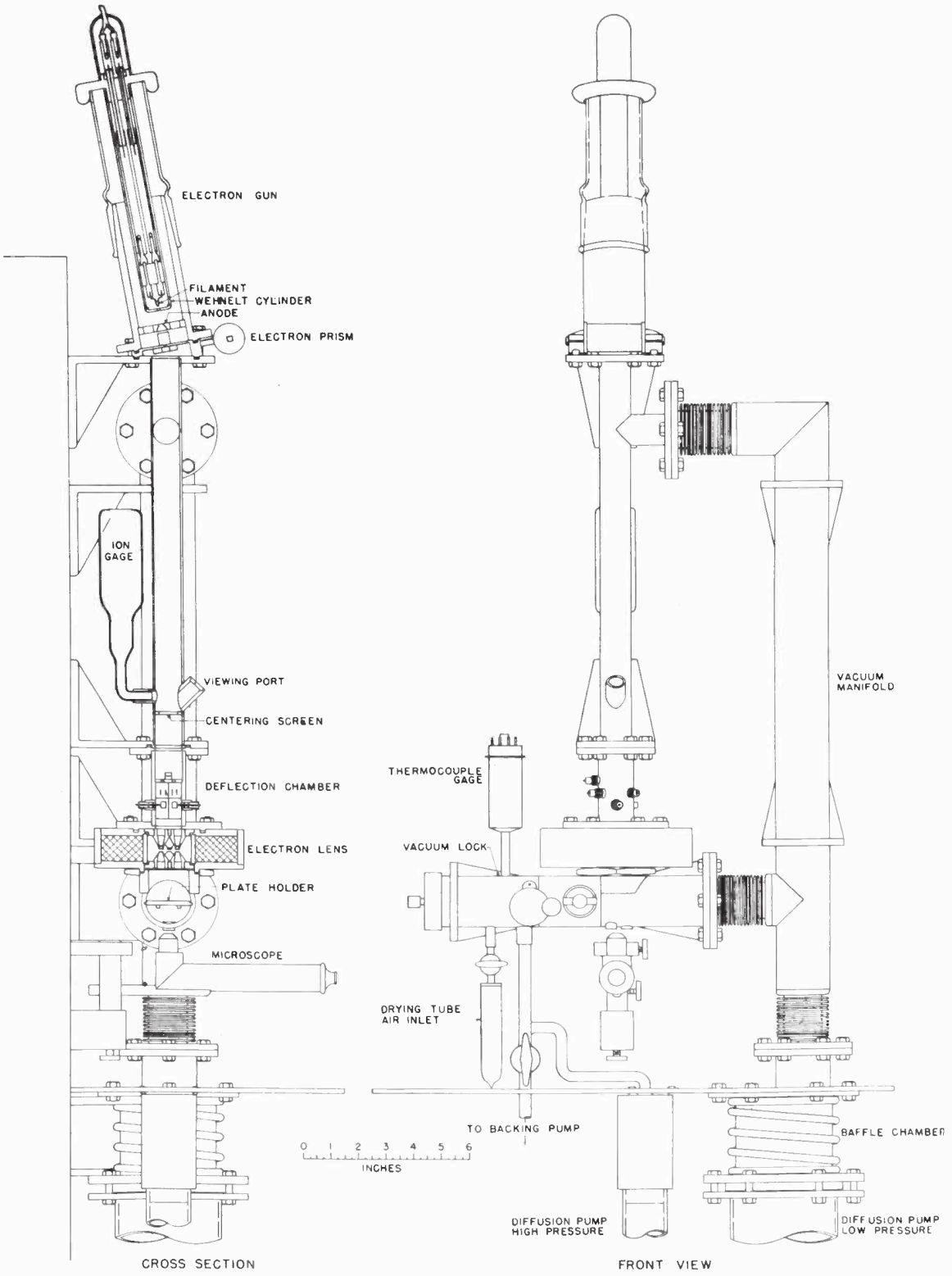

Fig. 3—Oscillograph assembly drawing.

the connections to the vacuum manifold, hydron bellows are used. The chief construction material is brass, and both hard and soft solders were used in making permanent joints. A vacuum as low as 5×10^{-6} millimeter of mercury may be maintained by the pumping system which consists of a glass-metal oil diffusion pump, using Octoil as the pumping fluid, backed by a two-stage mechanical pump. An ionization gage is used to measure the pressure during operation, and a thermocouple gage is used to determine when the diffusion pump may be turned on and to measure the pressure in the vacuum lock when photographic plates are exchanged.

To prevent undesired deflection of the beam by the earth's magnetic field, a cylindrical liner of 30-gage annealed high-permeability alloy extends from the electron gun to the deflecting-plate system.

A view of the complete oscillograph mounted on the chassis containing power supplies and vacuum-gage circuits is shown in Fig. 4. In the following paragraphs, various of the more important components will be described individually.

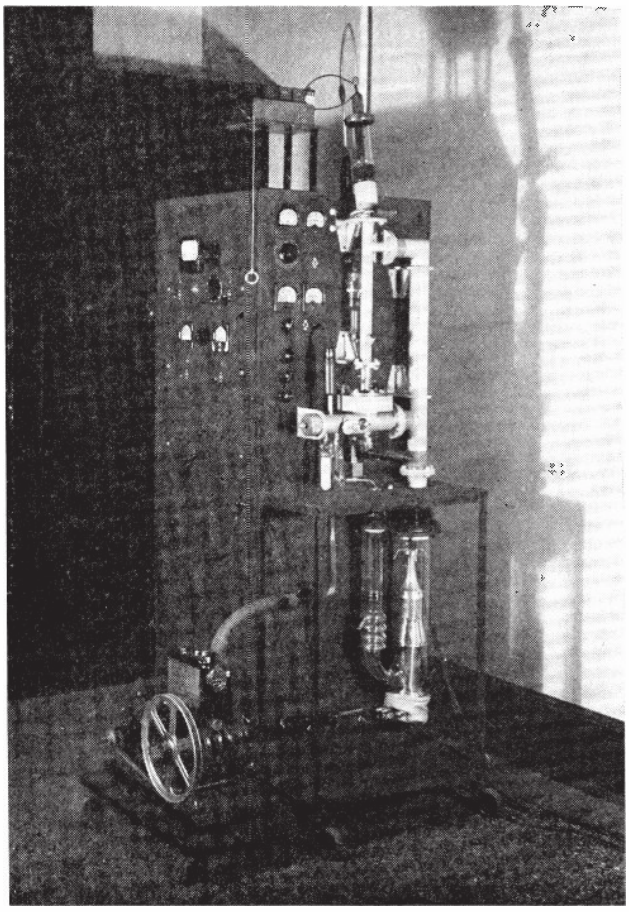

Fig. 4—Three-beam high-speed microoscillograph.

The electron gun, shown in Fig. 5, is of the hot-cathode type using a hairpin filament of 0.005-inch-diameter tungsten as the cathode. The filament is held in place by a simple set-screw arrangement to permit easy replacement and adjustment. A pyrex standard-taper ground joint insulates the corona shield, filament assembly, and Wehnelt cylinder from the anode tube. Apiezon "W" wax is used to make the vacuum-tight seals between the metal and glass portions of the assembly, except for the ground joint which is a grease seal. To prevent fogging of the photographic plate by

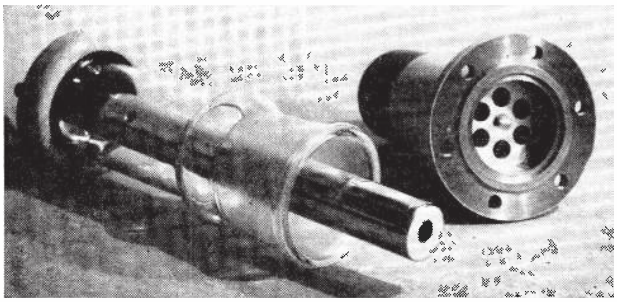

Fig. 5—Electron gun, partially disassembled.

direct light from the filament, the electron gun is tilted at an angle of 10 degrees with the main oscillograph body, and the electron beam is deflected through the angle by the magnetic field of an electromagnetic electron prism.

Incorporated in the main body of the oscillograph are a viewing port and annular fluorescent screen to aid in centering the electron beam. To prevent undesirable X-radiation of the operator while adjustments are being made, the viewing-port window is made of suitable lead glass.

Mechanical considerations and the desire to keep sensitivity and writing speed as high as possible dictated placing the deflection chamber on the electron-source side of the main lens. Included in the deflection chamber are a shielded pickup probe (used for triggering the sweep and phenomenon-initiating circuits as will be explained later), a three-aperture beam diaphragm,

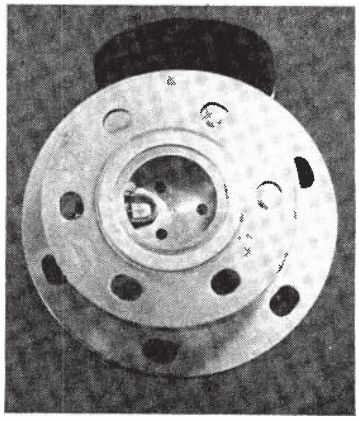

Fig. 6—Deflection chamber, top view showing shielded pickup probe and three-aperture beam diaphragm.

and the six pairs of deflecting plates. The deflecting plates are 0.2 inch long, 0.16 inch wide, with a separation of 0.14 inch. In each pair one plate is grounded and the other is waxed into a low-loss fused-quartz bushing.

The leads are designed to accommodate Sperry-type coaxial microwave fittings. An individual shielded compartment isolates each deflecting-plate pair from every other pair. A top view of the deflection chamber showing the shielded probe and three-aperture beam diaphragm is shown in Fig. 6. Fig. 7 is an external view showing the coaxial leads to the deflecting plates and probe. Fig. 8 is a bottom view showing the three pairs of plates normally used for time deflection and the lower three divisions in the shielding arrangement.

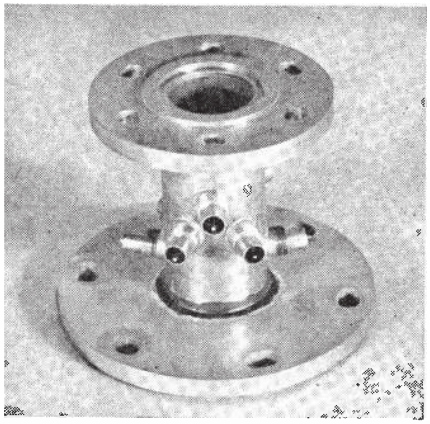

Fig. 7—Deflection chamber, external view.

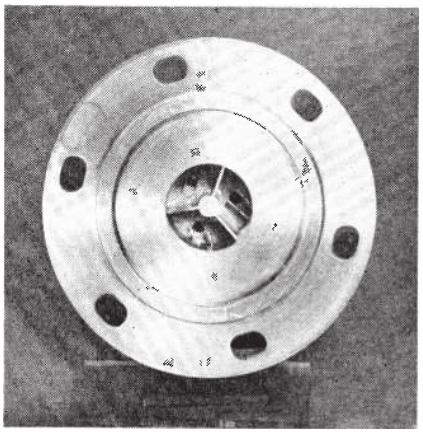

Fig. 8—Deflection chamber, bottom view showing the three lower plate pairs and shielding compartments.

The construction of the electron lens is shown by Fig. 9 in which the top pole-shoe carrier has been removed to reveal the interior. A single winding provides the magnetomotive force for the three parallel lens elements. To permit regulation of the coil current by a single receiving-type vacuum tube, a high-resistance, low-current winding of 20,000 turns is provided.

A close-up view of the vacuum lock and recording chamber together with the focusing microscope is shown in Fig. 10. The vacuum lock permits insertion and removal of photographic plates without breaking the vacuum on the main portion of the instrument. Removing one plate, inserting another, and establishing operating vacuum requires about 10 minutes. The plate holder is translated from the vacuum lock into recording position by a rack and pinion drive which enters the vacuum through a neoprene diaphragm known as a "Wilson seal."[6] The internal position of the plate holder is shown by an external indicator which is geared directly to the pinion drive shaft.

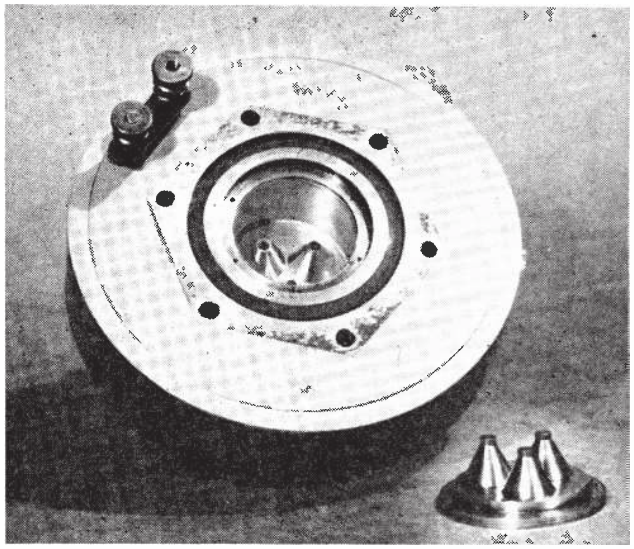

Fig. 9—Electron lens with top pole-shoe carrier removed.

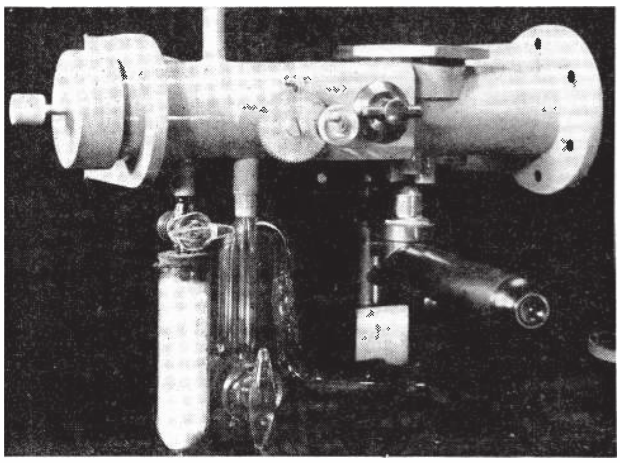

Fig. 10—Vacuum lock and recording chamber.

Fig. 11 shows the photographic-plate holder and light cover designed to take $1\frac{1}{4}$-by $1\frac{5}{8}$-inch plates. On a single plate, 8 complete sets or 24 oscillograms in all may be recorded. For focusing, a fine-grained translucent luminescent screen is attached to one end of the plate holder. The screen is viewed with the 42-power prism microscope through viewing ports on the under side of the recording chamber.

A block diagram of the circuits housed in the oscillograph chassis is given in Fig. 12. A voltage stabilizer of the saturable-core type is used to reduce line-voltage fluctuations to less than 1 per cent and thus reduce the range over which the electronic stabilizers must operate.

[6] R. R. Wilson, "A vacuum-tight sliding seal," *Rev. Sci. Instr.*, vol. 12, pp. 91–93; February, 1941.

The main high-voltage source is a conventional rectifier-doubler circuit, with a maximum output of 50,000 volts.

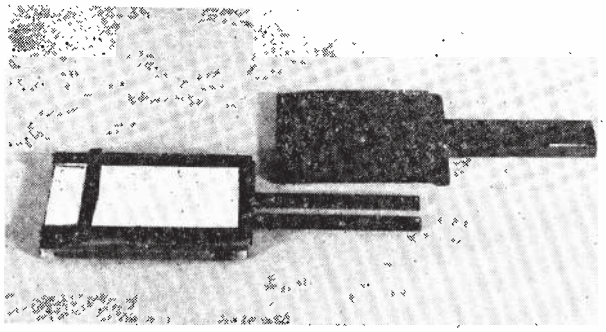

Fig. 11—Photographic plate holder and light cover.

A 5-megohm resistor is included in the high-voltage lead as a safety precaution, and during the short time of actual operation, it is short-circuited out by a manually-operated short-circuiting switch. The high voltage is stabilized to better than 0.05 per cent by a two-stage voltage-feedback circuit.

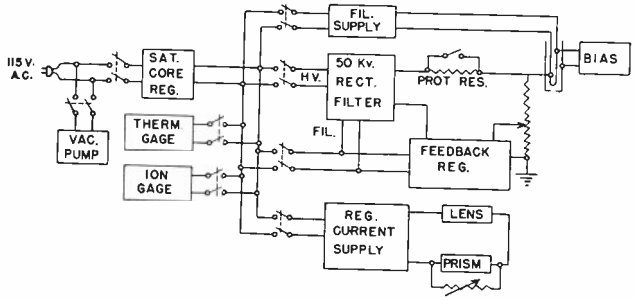

Fig. 12—Block diagram of circuits housed in oscillograph chassis.

The electron lens and prism current supply is taken from a design by Vance.[7] It more than adequately meets the oscillograph stability requirement of 0.05 per cent. Since the circuit regulates for both input-voltage variations and changes in output-circuit resistance, it is possible to operate the lens and prism winding in series by incorporating a variable shunt resistor across the prism winding to provide the necessary degree of independence in adjustment.

Bias supply for the electron-gun Wehnelt cyclinder is obtained from miniature dry-cell batteries. During standby the electron gun is biased beyond cutoff so that the photographic plate will not be fogged by scattered and secondary electrons. A tripping switch modeled after the principle of a double-action camera shutter is used to reduce the bias to the operating value for about 0.001 second. The switch is actuated by pulling on an insulating glass-fiber cord, the switch and bias batteries being mounted on an insulated platform as shown in Fig. 4.

Operation and Performance

Synchronization of the time sweep and phenomenon with the initiation of the electron beam is accomplished in the following manner. When the electron-gun bias is switched from cutoff to operating value, the full electron beam passes down the oscillograph and approximately 2 per cent of it strikes the pickup probe in the deflection chamber. Thus the probe acts as a constant-current source during this interval and may be used to actuate an electronic relay circuit, which in turn may initiate the sweep, the phenomenon, or both. For recording in the microwave region an accelerating voltage of 50,000 volts and a total beam current on the order of 5 milliamperes is used.

The deflection sensitivity of the instrument is 0.001 millimeter per volt on the recording plane. Since the trace diameter is 0.01 millimeter, the records may be enlarged 100 diameters to give an oscillogram of normal trace width. Thus the useful deflection sensitivity, referred to a trace width of 1 millimeter, is 0.1 millimeter per volt; or in other terms, the deflection factor is 10 volts per trace width.

To calculate the reduction in sensitivity owing to electron transit time through the deflecting fields, an effective plate length 40 per cent greater than the physical plate length of 0.2 inch was assumed to allow for fringing of the electric field at the ends of the deflecting plates. For 50,000 volts accelerating potential then, formula (1) gives a reduction in deflection sensitivity of 4 per cent at 3000 megacycles and 40 per cent at 10,000 megacycles.

For the generation of very fast single-sweep time bases, resistance-capacitance spark-gap circuits, and vacuum-tube circuits have been used. The spark-gap circuit has the advantage of simplicity, while a vacuum-tube circuit is much more reliable in synchronization characteristics.

Performance of the instrument is shown by the typical enlarged oscillograms shown in Figs. 13 through 16. Fig. 13 shows an oscillogram of a 3000-megacycle voltage obtained with a spark-gap sweep circuit. A vacuum-tube sweep circuit was used to record the 10,000-megacycle voltage shown in Fig. 14. The utility of the instrument in recording simultaneous phenomena is demonstrated by Figs. 15 and 16 in which current and voltage transients occurring in a particular circuit upon the breakdown of a spark gap are shown. The time scale was taken from a timing wave simultaneously recorded by the third beam.

In conclusion it may be said that a three-beam high-speed microoscillograph has been developed which extends the range of application of single-sweep oscillographic recording by a factor of approximately 10 in frequency over previous limits imposed by conventional high-speed oscillographs. The instrument in its present state of development opens up entirely new fields of research for the application of oscillographic techniques. Some of these are microwave transients, reflection and traveling-wave phenomena on small systems, and research on the fundamental electric-breakdown characteristics of dielectrics using very steep impulse voltages.

[7] A. W. Vance, "Stable power supplies for electron microscopes," *RCA Rev.*, vol. 5, pp. 293–300; January, 1941.

Fig. 13—Single-sweep oscillogram of 3000-megacycle voltage. Enlargement, 100 diameters.

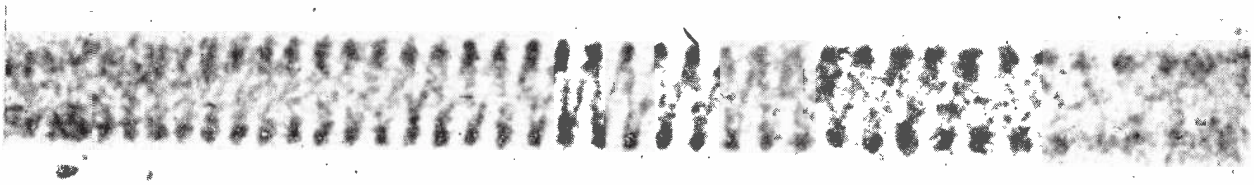

Fig. 14—Single-sweep oscillogram of 10,000-megacycle voltage. Enlargement, 100 diameters.

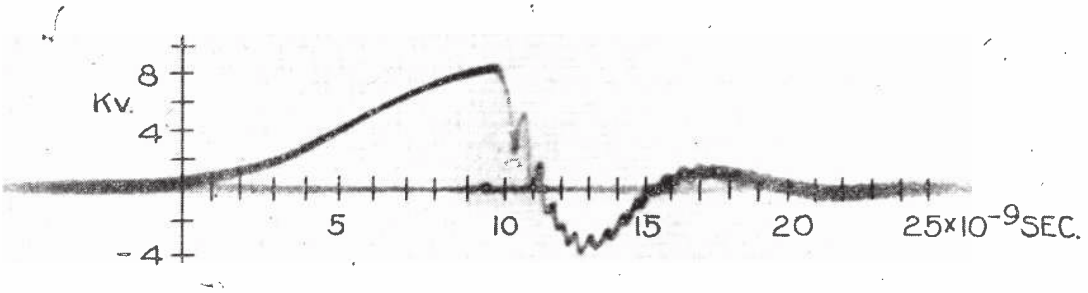

Fig. 15—Voltage transient in spark-gap circuit. Enlargement, 50 diameters.

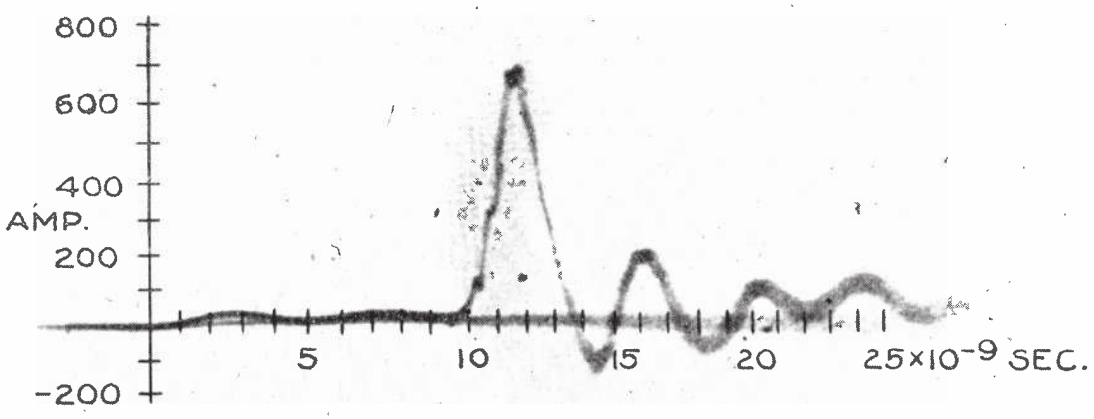

Fig. 16—Current transient in spark-gap circuit recorded simultaneously with voltage transient in Fig. 15. Enlargement, 50 diameters.

Acknowledgment

This development was made as part of the program of the Laboratory for Insulation Research, Department of Electrical Engineering, Massachusetts Institute of Technology, in partial fulfillment of the requirements for the Doctor of Science degree in electrical engineering, and was financed in part by a grant from the General Radio Company, of Cambridge, Massachusetts The writer also wishes to acknowledge the constant encouragement and helpful counsel of Professor Arthur R. von Hippel, Director of the Laboratory for Insulation Research; the co-operation of Mr. George Gale, who performed the major part of the machine shop work; and the welcome suggestions and assistance of Dr. Demetrius Jelatis, Mr. Merlin Haugen, and Mr. Robert Fletcher in setting up microwave equipment used in part of the research.

Synchronizing Generators for Electronic Television*

A. RUFUS APPLEGARTH†, ASSOCIATE, I.R.E.

Summary—**The system of electronic circuits employed to generate the complex wave forms required as a base for television picture transmission is described. It comprises four principal sections which are: (1) source of accurately timed pulses; (2) frequency-divider chain; (3) components-generating circuits; and (4) signal-synthesis circuits. The various means for accomplishing these functions is briefly discussed, and illustrated by circuits which have been used successfully for such purposes in practical applications.**

I. Introduction

MUCH has been written about the general subject of television. There are available several good texts which discuss the general requirements of television systems, but which do not delve into the problems involved in generating the modern electronic-television synchronizing signal. The subject matter of this paper includes a discussion of the problems concerning the design of synchronizing generators and also some detailed circuits to illustrate the discussion.

The synchronizing generator is the heart of any electronic-television system. It provides the many component synchronizing and pedestal signals to which the picture signal, having been generated and amplified elsewhere, is added to form the complete composite video signal. This video signal is then modulated upon a suitable carrier for radio-television transmission. The basic components of a television synchronizing generator are illustrated in Fig. 1. It is necessarily a complex assembly of electronic devices, interlocked in such a way as to produce a stable composite signal which must conform to the standards set by the Federal Communications Commission (see Fig. 2).

The Federal Communications Commission standards specify an interlaced scan. The timing of the vertical scan must be precisely related to that of the horizontal scan, if accurate interlacing is to be obtained. Not only must the horizontal and vertical scanning frequencies be harmonically related, but precisely controlled in relative phase position as well. For example, a shift in the timing of the vertical scan by an interval equal to one half of a horizontal line will completely destroy the interlace. Furthermore, the maintenance of a satisfactory interlace (defined as one in which the unbalance between adjacent line spacing is no greater than 40 to 60 per cent) requires that timing precision be held to 0.1 line, or to one part in 5250 in a 525-line system. Such narrow tolerance restrictions in the timing between horizontal and vertical scanning frequencies preclude most of the simple harmonic-generating systems used successfully for other purposes.

* Decimal classification: R583. Original manuscript received by the Institute, July 2, 1945.

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The design of electronic synchronizing generators generally includes a high-frequency master oscillator from which the various signal components are derived by frequency-divider systems and wave-shaping circuits. It is desirable to have the 60-cycle vertical-scanning frequency synchronous with the 60-cycle power system of the local utility, to eliminate the slow vertical drift imparted to any hum pattern which might originate anywhere in the over-all television system.

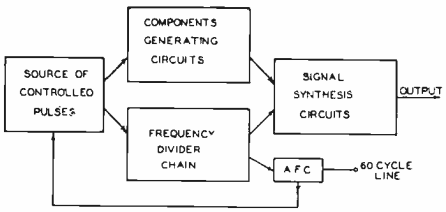

Fig. 1—Block diagram of synchronizing generator showing principal components.

Television standards for some years have included a line structure specifically chosen to facilitate frequency-divider design. The frequency-division ratio to relate the vertical scan to the second harmonic of the horizontal scan is equal to the number of lines. Thus, for easy frequency-divider design, the number of lines must be a number capable of being broken into several small prime factors. For example, 343 could be factored into $7\times7\times7$. Likewise, 441 can be factored into $3\times3\times7\times7$, and 525 into $3\times5\times5\times7$. Future standards undoubtedly will be chosen to factor similarly. The illustrative circuits described herein are designed for the 525-line standard, but, by suitable modification, could be made to function on any standard likely to be adopted for some time to come.

II. The Frequency-Divider Chain

As pointed out above, the system of circuits called the frequency-divider chain which links the vertical-scanning frequency to the second harmonic of the horizontal-scanning frequency forms a vital part of the synchronizing generator. Various circuits can be used for the several links of the chain, including multivibrators, blocking-tube oscillators, and counters.

The multivibrator comprises two resistance-coupled amplifier stages in cascade, with the output of the second stage fed directly back to the input of the first stage, to form an oscillator (see Fig. 3a). The frequency of oscillation is determined primarily by the time

constants of the coupling networks, but depends also on the tube characteristics, power-supply voltages, and the amplitude of the driving signal. The multivibrator offers a versatile means for generating oscillations of rectangular wave form, but its stability is inadequate for its use as a frequency divider for factors greater than about 3:1.

The blocking-tube oscillator represents a distinct improvement in stability over the multivibrator (see Fig. 3b). This improvement comes primarily from the substitution of a transformer of inherently stable characteristics for one of the tubes of the multivibrator. This type of oscillator, although more stable, is also subject to frequency dependence upon tube characteristics, power-supply voltage variations, and the amplitude of the driving signal used to synchronize it.

A resonant stabilizer comprising a parallel-connected tuned circuit can be inserted in series with the oscillator grid circuit to increase greatly its frequency stability. This will cause it to divide by a factor primarily determined by the tuning of the resonant circuit, and to a far lesser degree by unwanted variables (see Fig. 4).

The resonant stabilizer is shock excited by the pulse of grid current that flows through it during the positive-grid portion of each cycle. The voltage that appears across the stabilizer is a damped transient oscillation whose period is determined by the tuning of the resonant stabilizer. This transient voltage, which is repeated each time a pulse of oscillator-grid current flows, is added to the exponential capacitor-discharge voltage, and to the train of driving pulses to form the composite oscillator-grid signal. Thus, by tuning the stabilizer to the proper frequency (about one and one-half times the desired oscillator frequency) the transient oscillation will elevate the desired driving pulse substantially above its neighbors, and thereby insure synchronization of the blocking-tube oscillator on the desired driving pulse, despite the usual variations in tube characteristics, power-supply voltages, and the amplitude of the driving pulses.

The stabilizing effect increases as the amplitude of the damped transient signal is increased, up to the point where this transient signal becomes strong enough to fire the blocking-tube oscillator without the aid of the

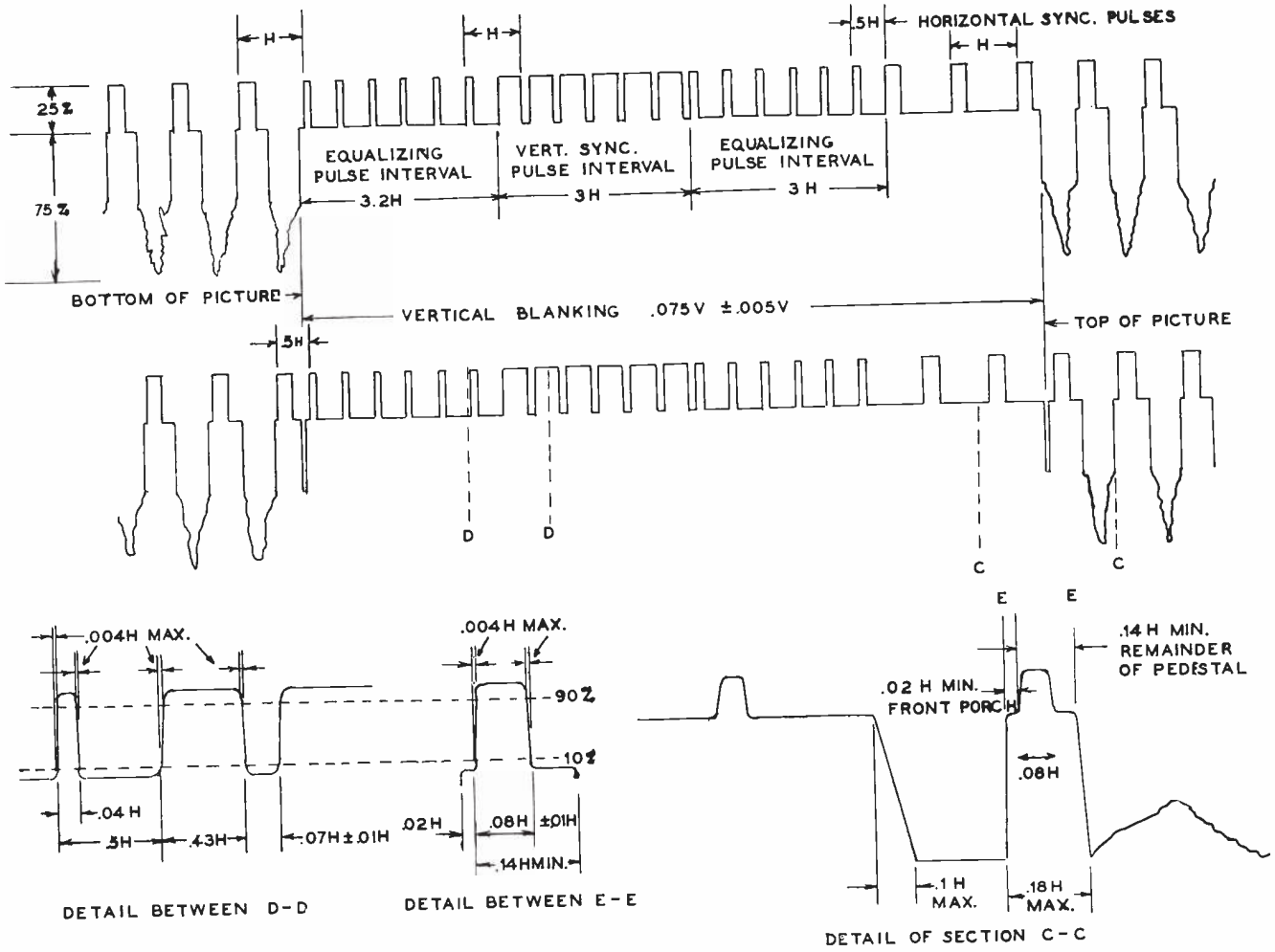

Fig. 2—Federal Communications Commission's standard television signal.

desired driving pulse, which defeats the purpose of the stabilizer. The amplitude of the stabilizing signal is determined by the magnitude and wave form of the pulse of grid current exciting it, and by the Q and resistance-capacitance ratio of the resonant stabilizer. The Q should be made as high as conveniently practicable, and the final amplitude of the stabilizing signal set by adjusting the resistance-capacitance ratio.

Pulse-counting circuits similar to the one shown in Fig. 3c are frequently used as frequency dividers. They usually comprise blocking oscillators in which the grid-leak resistors are replaced by a pair of diodes. The driving signal is applied to the oscillator grid capacitor through a diode to cause the voltage to be built up in a series of steps. The circuits are adjusted so that the desired firing pulse causes the blocking-tube oscillator

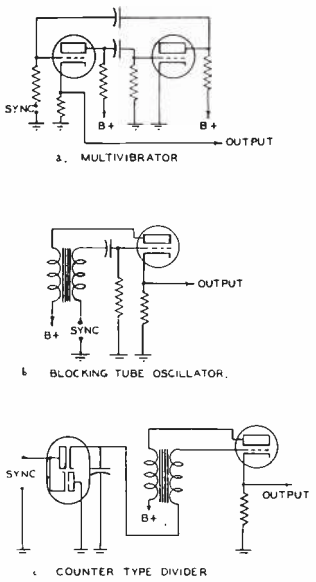

Fig. 3—Frequency-divider circuits.

to fire on the top step, thus discharging the grid capacitor to complete the cycle.

The frequency divider shown in Fig. 5 comprises four stages, dividing in the ratios $3\times5\times5\times7$ to reduce 31,500 cycles per second to 60 cycles per second, for use in a 525-line television system.

III. The Master Oscillator and Automatic-Frequency-Control System

The master oscillator should be a fairly stable sine-wave oscillator whose frequency can be readily controlled by a reactance tube. The drift stability is not of great importance, since the frequency average is maintained through automatic frequency control, but a high degree of cycle-to-cycle regularity, difficult to obtain in relaxation-type oscillators, is necessary to produce a television picture with straight vertical edges.

The transitron oscillator is well suited to this purpose. It is a very simple circuit of inherently high stability requiring simple components. The frequency of the master oscillator should be set to the second harmonic of the horizontal-scanning frequency, which is the fundamental of the frequency used for the equalizing pulses and the serrated vertical-synchronizing blocks. For a 525-line picture (30 frames per second) this would be 31,500 cycles per second, as determined by multiplying

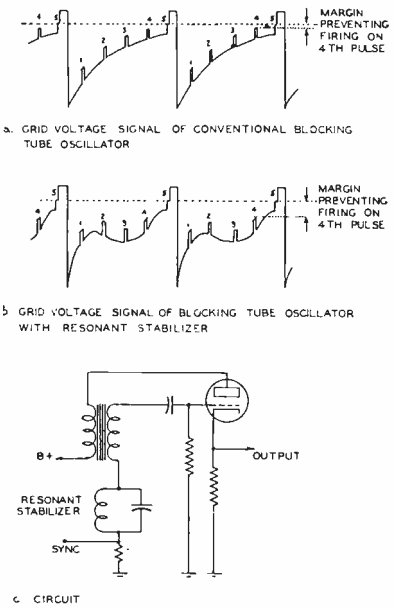
MARGIN PREVENTING FIRING ON 4TH PULSE
a. GRID VOLTAGE SIGNAL OF CONVENTIONAL BLOCKING TUBE OSCILLATOR
MARGIN PREVENTING FIRING ON 4TH PULSE
b GRID VOLTAGE SIGNAL OF BLOCKING TUBE OSCILLATOR WITH RESONANT STABILIZER
B+
OUTPUT
RESONANT STABILIZER
SYNC
c CIRCUIT

Fig. 4—Stabilized frequency divider.

the number of lines by the number of frames per second and by the interlace ratio ($525\times30\times2=31{,}500$).

The reactance tube in the circuit illustrated in Fig. 6 is of conventional design, employing a resistance-capacitance network bridged between grid and plate to provide a grid excitation shifted approximately 90 degrees in phase from the plate voltage. The reactance-control circuit should have sufficient frequency-control range to

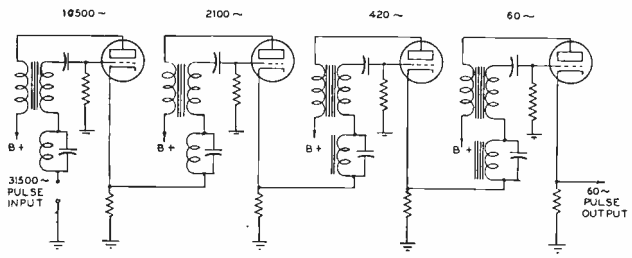

Fig. 5—Schematic diagram of frequency-divider chain.

correct for any drift of the master oscillator, but should not be locked so tightly to the oscillator as to cause reasonable line-voltage fluctuations (particularly momentary phase disturbances) to introduce frequency variations in the master oscillator of sufficient magnitude to show as irregularities in the vertical edges of the picture.

The direct-current frequency-control signal is derived from a phase discriminator sensitive to phase-angle variations between the 60-cycle output from the

frequency-divider chain and the 60-cycle signal taken from the power line. The time constant of the control circuit must be made high enough to prevent sudden power-line irregularities of momentary duration from affecting the master oscillator. A circuit suited to this purpose is shown in Fig. 6. The signal from the 60-cycle vertical-blanking (pedestal) multivibrator is used as a driving source because it is the widest 60-cycle pulse used as a component part of the composite synchronizing and pedestal signal. This wide pulse is amplified, and partially shaped into a sine wave by the tuned secondary of the audio transformer. The Q of the resonant-transformer secondary is so low that the wave form across it more nearly resembles a saw tooth, but it is usable as such. The circuit of the discriminator, as shown, is similar to the one commonly used as a detector for frequency-modulation, but the tuning of the transformer plays no active part in the functioning of the device other than wave shaping. The discriminator develops a direct-current output dependent upon the relative phase of the two input signals.

made up of precisely timed "edge" signals connected by constant voltage-time intervals represented by the straight horizontal portions of the wave forms. The multivibrator is ideally suited to generating such signal components, because they can be precisely synchronized and the pulse width can be controlled easily. The stability of such circuits is adequate, if they are not expected to subdivide frequencies by large factors.

Some component wave forms may also be derived by a wave-shaping process not requiring synchronized oscillators. This method of generating prescribed wave forms is to be preferred where the circuits involved are simple, and do not require critical tube characteristics or operating voltages. It is also the best means for generating component wave forms which do not require such close pulse-width control, such as the set of serrated vertical-synchronizing blocks.

The keying signals, particularly the one for inserting the group of six vertical synchronizing blocks, must be timed with high precision. This accuracy in timing is necessary to insure eventual synthesis of signal groups

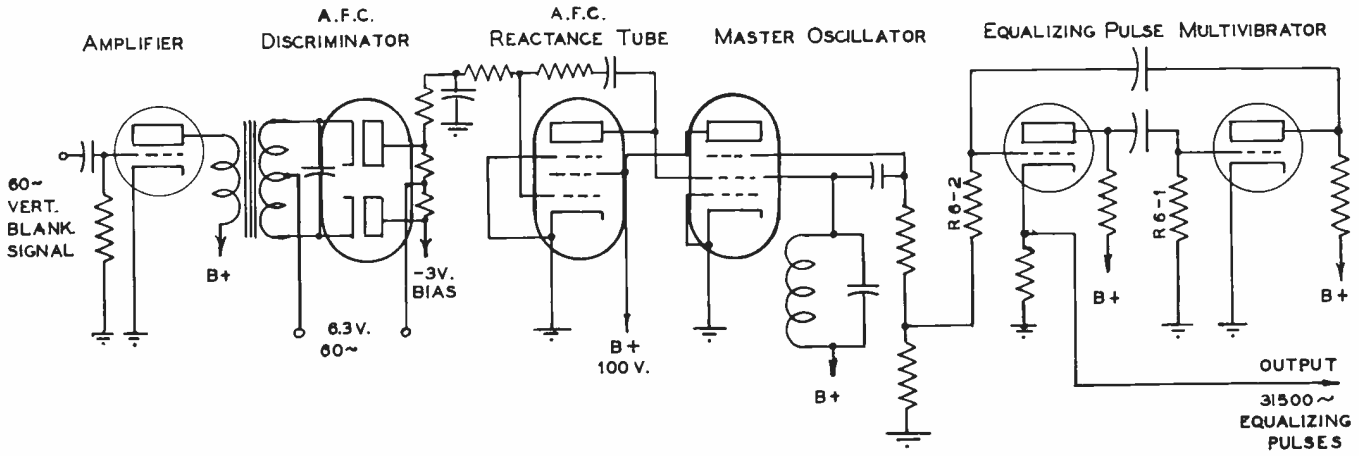

Fig. 6—Master oscillator and automatic-frequency-control system.

IV. The Components-Generating Circuits

The next logical step in the design of a television-synchronizing generator is to produce the various component wave forms that comprise the complete signal. An analysis of the Federal Communications Commission standard television signal (see Fig. 2) discloses that it is made up of five different periodic wave forms, plus the picture signal, lasting for time intervals from a few closely spaced pulses to an appreciable fraction of the 60-cycle period. These various component signals are most easily generated as continuous trains of pulses, or blocks, for later modulation into groups suitable for composite-signal synthesis.

The derivation of certain desired wave forms from related source signals is a fascinating branch of the electronic art. The television synchronizing and pedestal signals comprise essentially rectangular wave forms, containing the correct number of pulses or blocks, with smooth and correctly timed change-overs.

A. The Equalizing-Pulse Signal

Two groups, each containing six narrow pulses that are half as wide as normal horizontal-synchronizing pulses but spaced at half-line time intervals, form a part of the composite synchronizing signal. One such group is transmitted immediately prior to the vertical synchronizing signal, and the other immediately following it. Their purpose is to equalize the two sets of alternate fields which comprise a frame, but which are staggered one-half line apart in order to produce the interlace, so that they are made identical for a short interval before and after the vertical-synchronizing signal. Thus, simple signal-integrating circuits can be used in television receiving apparatus to separate the vertical-synchronizing

signal from the remainder of the composite signal.

A continuous train of equalizing pulses would have a frequency of 31,500 cycles per second. This has been previously chosen as the master-oscillator frequency, and so a multivibrator, or other means for generating the signal, can be driven by the master oscillator as shown in Fig. 6. The pulse width of this multivibrator can be adjusted to standard by *R6-1*, after which *R6-2* can be reset for tightest synchronization to the master oscillator. Both resistances can be replaced by fixed units of suitable value, since the exact pulse width is not critical, and the synchronization at fundamental frequency is very tight.

The output of this multivibrator can be used for many purposes including driving the frequency-divider chain, driving the horizontal-pedestal and synchronizing-pulse oscillators (dividing 2:1 in frequency), generating the vertical-synchronizing block signal, and providing a reference leading edge for all of the synchronizing-signal components, in addition to the direct generation of the equalizing-pulse signal.

B. The Horizontal-Pedestal Signal

The horizontal-pedestal signal, or blanking signal as it is sometimes called, forms the base on which the picture signal is later built. It also serves to black out the television-receiver screen during the flyback of the horizontal scan. The frequency of this signal must be equal to the horizontal scanning rate, which is 15,750 cycles per second for a 525-line, 30-frame-per-second, 2:1-interlaced picture.

In order to facilitate the separation of the synchronizing signals from the picture and pedestal signals in the television receiver, particularly under conditions of adverse radio transmission, the edges of the horizontal pedestals terminating each line are made to precede the leading edge of the horizontal synchronizing pulses by a small but definite time interval sometimes referred to as the "front porch" (see Fig. 7d). Since the horizontal-pedestal signal is derived from the equalizing pulses by synchronization, and since time cannot be anticipated, the firing of the horizontal-pedestal oscillator relative to the leading edges of the equalizing pulses driving it is delayed by a time interval of slightly less than one half line (the interval between equalizing pulses).

A means for accomplishing this time delay is shown in Fig. 7. It consists of forming a saw-tooth signal by integration of the equalizing pulses and using a portion of this signal to fire the horizontal-pedestal multivibrator. The range of adjustment should be limited to a few per cent of the horizontal-scan period, or the control may be replaced by suitable fixed resistances since the exact length of the "front porch" is not critical provided that timing of the horizontal-synchronizing pulses does not depend on it, as is incorporated in this design.

A multivibrator is suggested as the pedestal oscillator as shown in Fig. 7. The pulse width is determined by resistance *R7-2*, and the "front-porch" interval set by the adjustment of voltage divider *R7-1*.

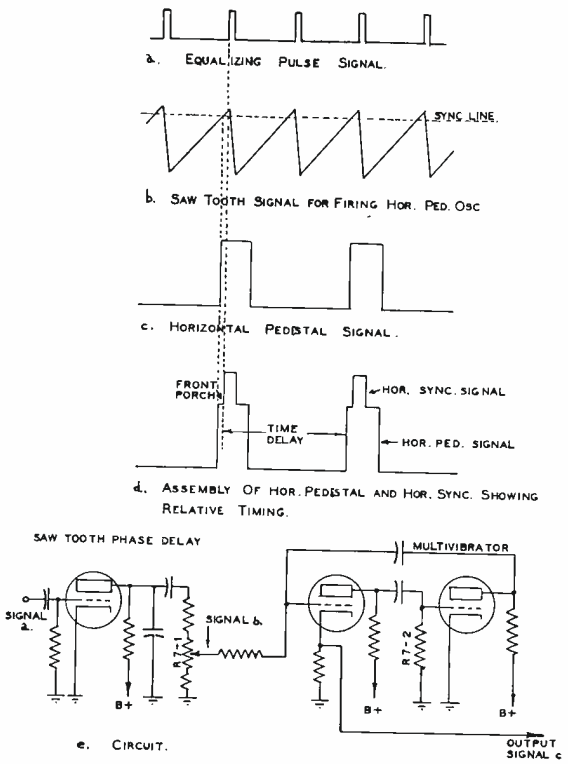

Fig. 7—Horizontal-pedestal multivibrator system.

C. The Horizontal-Synchronizing Pulse

Synchronization of the horizontal-scanning system of the television receiver depends directly upon the transmission of accurately formed and timed horizontal-synchronizing pulses, except for short time intervals during the transmission of the equalizing pulses and the vertical-synchronizing blocks.

The horizontal-synchronizing pulses must be timed to coincide approximately with the wider horizontal-pedestal pulses. Thus, if they are to be synchronized separately by the source of equalizing pulses which occur at twice the horizontal-repetition rate, means must be provided to guard against the possibility of the two horizontal-signal components synchronizing on alternate equalizing pulses.

It is entirely possible to use the horizontal-pedestal pulses to fire the horizontal-synchronizing-pulse oscillator through a time-delay network similar to the one used to delay the firing of the horizontal-pedestal oscillator. However, by so doing, the timing of the leading edges of the horizontal-synchronizing pulses relative to the leading edges of the equalizing pulses and vertical-synchronizing blocks will become dependent upon the sum of the two time-delay adjustments, creating an undesirable situation. The use of an alternate equalizing-pulse selector, or modulator, whereby the proper set of alternate equalizing pulses for the synchronization of the horizontal-synchronizing-pulse oscillator is selected by the horizontal-pedestal signal is to be preferred (see

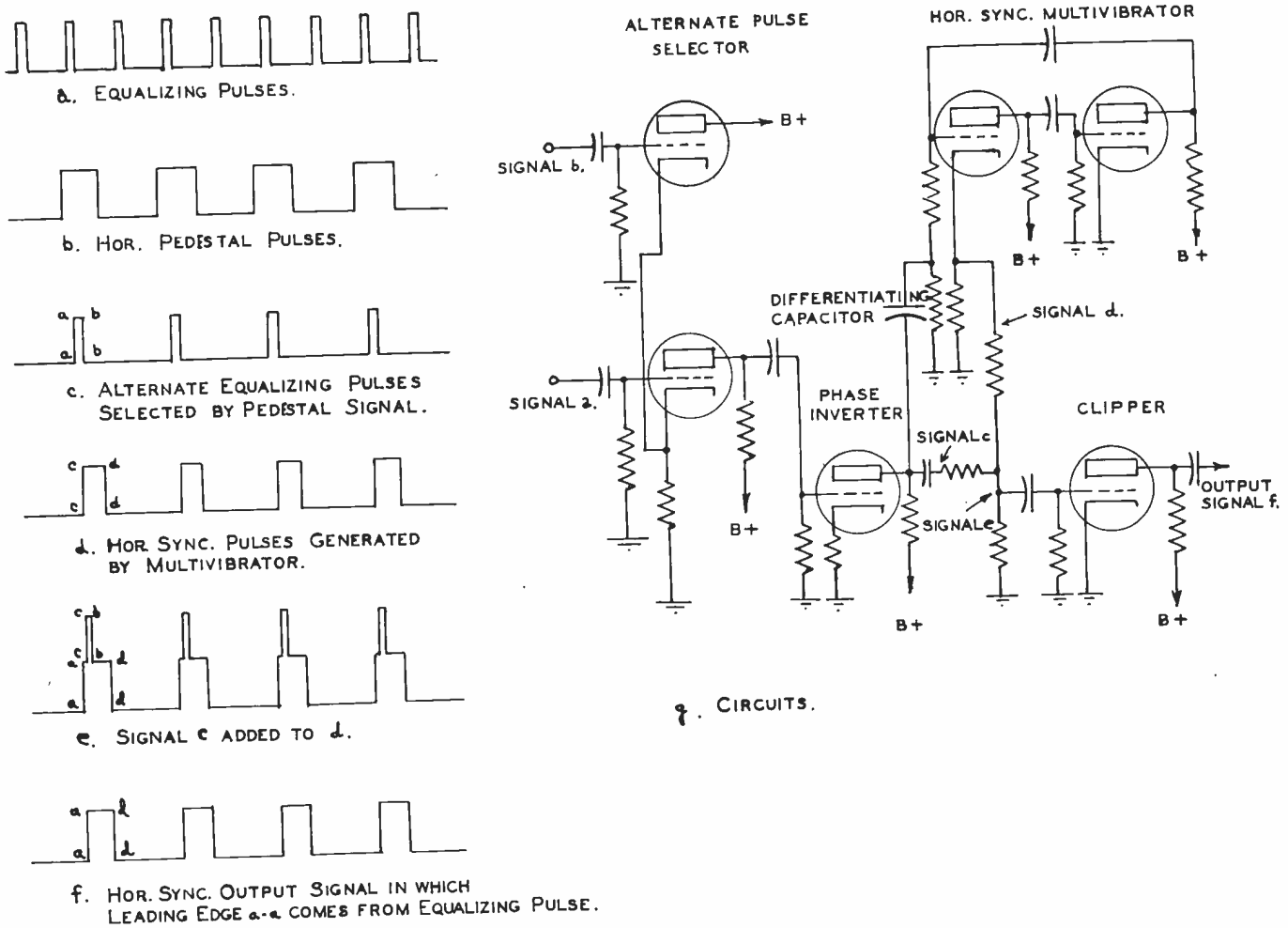

Fig. 8—Horizontal-synchronizing-pulse generating system.

Fig. 8). Thus, the adjustment of the "front-porch" time delay over a reasonable range cannot affect the timing of the horizontal-synchronizing pulses.

The horizontal-synchronizing-pulse oscillator may well be another multivibrator, as shown in Fig. 8. Resistance *R8-1* controls the pulse width. The problem of mixing the selected equalizing-pulse signal with the generated horizontal-synchronizing-pulse signal will be discussed in the section devoted to signal-synthesis circuits.

D. The Vertical-Synchronizing Blocks

The synchronization of the vertical-scanning system of the television receiver is accomplished by integrating a series of six wide pulses, or blocks, which are transmitted as a component of the composite synchronizing signal. These groups of blocks must be identical for each of the interlaced fields comprising a frame if a satisfactory interlace is to be obtained in the receiver. As explained previously, the equalizing pulses which precede and follow this group of vertical-synchronizing blocks help further to unify the composite synchronizing signal to facilitate the interlace. The vertical-synchronizing signal is serrated, or split, into blocks, so as not to interrupt the regularly timed firing of the horizontal-scanning system during the transmission of the vertical-synchronizing signal.

An oscillator could be used to generate these blocks, or inverted pulses, if properly synchronized by the equalizing pulses, but for this application wave-shaping circuits can be used to reshape the equalizing pulses into suitable blocks. The advantage resulting from this practice is the substitution of a highly stable system for a relatively unstable synchronized oscillator where it is not necessary to have the high degree of pulse-width flexibility obtainable from the multivibrator. Fig. 9 shows such a system of circuits. The equalizing pulse is formed into a saw tooth and thence clipped in two successive stages to produce the desired wave form.

E. The 60-Cycle Keying Signals

Two 60-cycle keying signals are required for the eventual synthesis of the composite signal. One such keying signal is used to interrupt the otherwise continuous transmission of the horizontal-synchronizing pulses for a time interval corresponding to nine such pulses, and to insert in their stead a group of eighteen equalizing pulses. The other 60-cycle keying signal is used to add the group of six vertical-synchronizing blocks to the center six equalizing pulses of the above selected group. This one is referred to as the 60-cycle, 3-line keying signal.

The final 60-cycle, blocking-tube oscillator of the frequency-divider chain can be used as the 60-cycle 9-line keying signal, if it is designed to produce a pulse of the proper width.

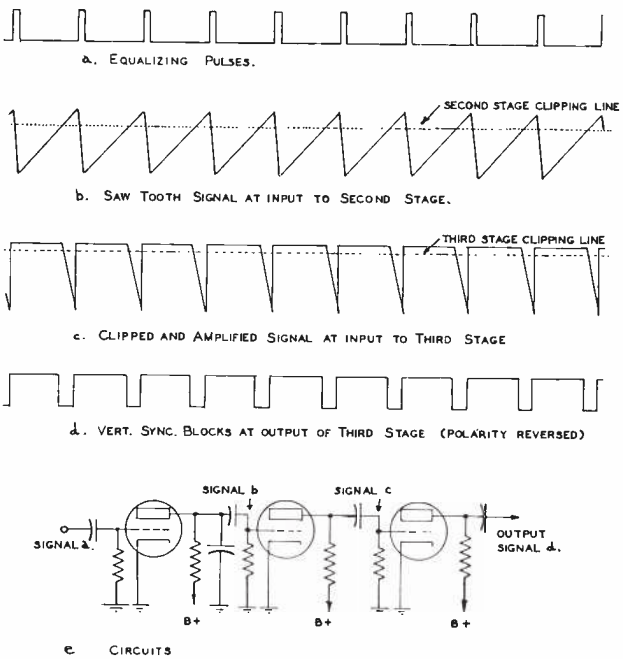

Fig. 9—Shaping circuits for generating the vertical-synchronizing blocks.

The 60-cycle 3-line keying signal must be more precisely controlled. It can be either a properly designed multivibrator or a simple blocking-tube oscillator, or can be derived from the 60-cycle 9-line keying signal by suitable wave-shaping circuits. Experience has shown that the blocking-tube oscillator provides a satisfactory solution to the problem.

The timing of the leading edge of the 60-cycle 3-line keying signal is very critical and must be held within the time interval represented by the width of an equalizing pulse. The most certain means for accomplishing this degree of precision is to fire the oscillator generating the 60-cycle 3-line signal from the leading edge of a particular equalizing pulse. Synchronization on the leading edge can be obtained readily by electrical differentiation of the equalizing pulse prior to its use for the synchronization of the 60-cycle 3-line oscillator. The more difficult problem is to insure synchronization on the particularly chosen equalizing pulse out of the 525 which are generated during each 60-cycle period.

A means for obtaining the required timing precision with proven stability is shown in Fig. 10. The 60-cycle 9-line keying signal, which is used to time the keying

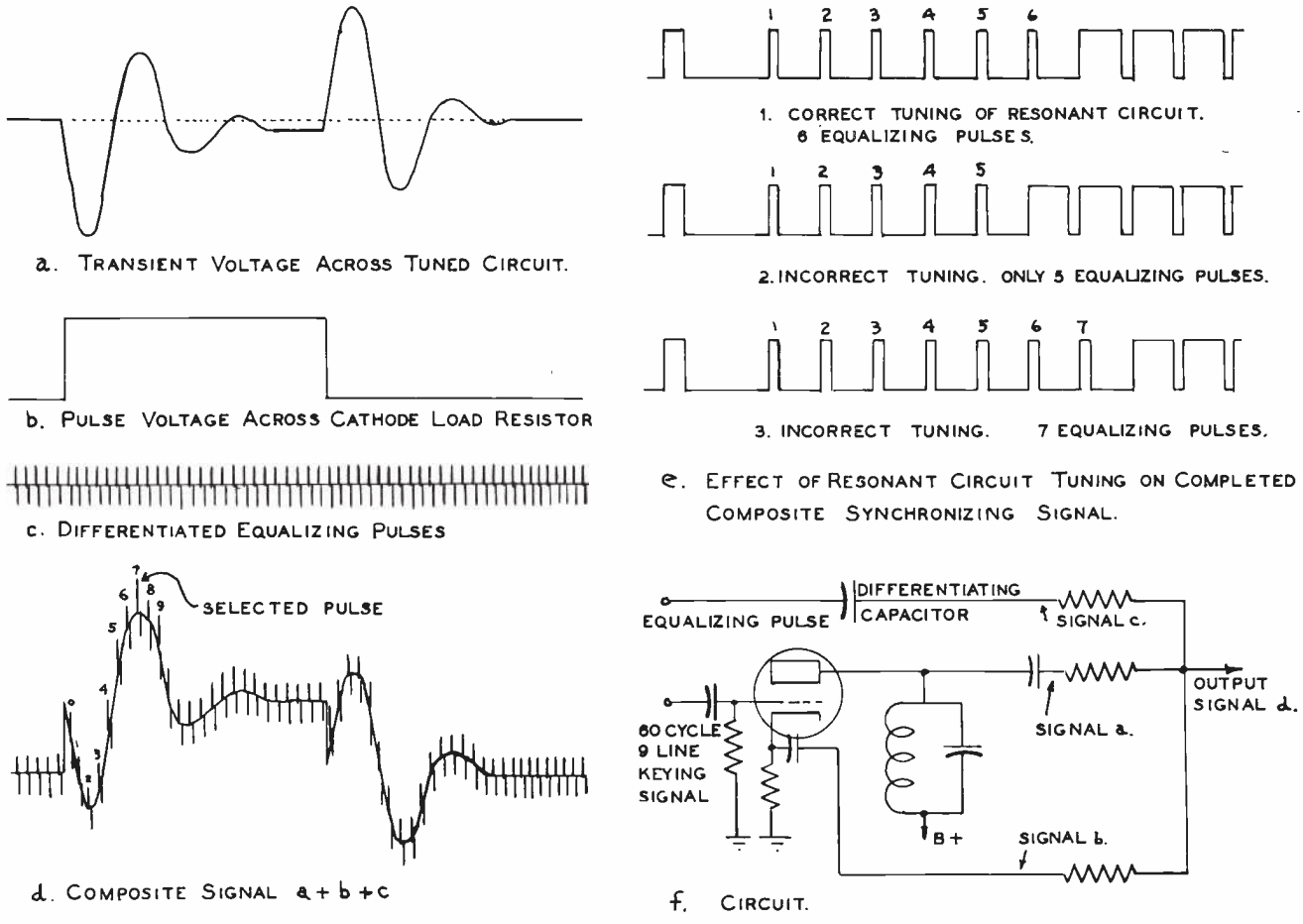
a. TRANSIENT VOLTAGE ACROSS TUNED CIRCUIT.
b. PULSE VOLTAGE ACROSS CATHODE LOAD RESISTOR
c. DIFFERENTIATED EQUALIZING PULSES
SELECTED PULSE
d. COMPOSITE SIGNAL a + b + c
1 2 3 4 5 6
1. CORRECT TUNING OF RESONANT CIRCUIT. 6 EQUALIZING PULSES.
1 2 3 4 5
2. INCORRECT TUNING. ONLY 5 EQUALIZING PULSES.
1 2 3 4 5 6 7
3. INCORRECT TUNING. 7 EQUALIZING PULSES.
e. EFFECT OF RESONANT CIRCUIT TUNING ON COMPLETED COMPOSITE SYNCHRONIZING SIGNAL.
EQUALIZING PULSE
DIFFERENTIATING CAPACITOR
SIGNAL c.
OUTPUT SIGNAL d.
60 CYCLE 9 LINE KEYING SIGNAL
SIGNAL a.
B+
SIGNAL b.
f. CIRCUIT.

Fig. 10—Details of precision time-delay system.

of the equalizing-pulse group, is also used to drive a pulse of current through a resonant circuit, causing it to develop two trains of damped sinusoidal oscillations, one following each pulse edge. The resonant circuit is tuned so that the second half cycle of the damped oscillations following the excitation produced by the leading edge of the 60-cycle, 9-line signal can serve as a pedestal to elevate the seventh equalizing pulse following the leading edge of the 60-cycle 9-line signal. The use of the second half cycle for pulse selection results in a gain in pulse selectivity of about three times, as compared to the use of the first half cycle. This improvement results from the obvious fact that the frequency to which the resonant circuit must be tuned is three times as great when the desired time interval is three quarters of a cycle as compared to one-quarter cycle (peak of the transient).

The second half cycle of a highly damped transient oscillation is considerably reduced in amplitude as compared to the first half cycle. Thus, if the polarity of the transient signal is chosen to cause the second half cycle of the initial damped oscillation excited by the leading edge of 60-cycle, 9-line pulse to reinforce the desired equalizing pulse, the first half cycle of the second train of damped oscillations excited by the trailing edge of the 60-cycle, 9-line pulse will be greater in amplitude than the desired reinforcement signal, and will probably cause erroneous synchronization. The resistance component of the inductor forming part of the tuned circuit adds a voltage component of the same wave form as the 60-cycle 9-line pulse, which further accentuates the undesired reinforcement. Both of these factors can be overcome by mixing with the transient oscillations and differentiated equalizing pulses a third component comprising a 60-cycle, 9-line pulse of proper polarity to elevate the initial transient relative to the second one (see Fig. 10). The result of adding the three components is to produce a very precise synchronizing signal for the 60-cycle 3-line oscillator, accurate to about one part in 25,000, without requiring any critical circuits. The tuning of the resonant circuit is the only adjustment, and its tolerance is about ± 10 per cent in resonant frequency.

F. The Vertical Blanking Signal

The vertical-blanking signal corresponds in the vertical-scanning system to the horizontal pedestal. It is sometimes called the vertical-pedestal signal, and it serves to black out the television-receiver screen during the vertical flyback, but does not serve as a base upon which to build the picture signal, as does the horizontal pedestal.

The timing of this signal is not of great importance so long as it comes within a line or two of its specified phase relative to the vertical-synchronizing signal. It is a wide pulse, and therefore a multivibrator is suggested. The frequency should be 60 cycles per second, and simple synchronization from the leading edge of the 60-cycle, 9-line keying signal will suffice. The output signal from this oscillator is also used to drive the discriminator for the automatic frequency control of the master oscillator (see Fig. 6).

G. Conclusions

It seems advisable at this point to tabulate the various signals (Table I) that have been generated, before proceeding with the synthesis of these signal components into the composite television signal.

TABLE I

Signal	Frequency	Wave form	Timing Source
Master oscillator	31,500	sine wave	power line through automatic-frequency-control system
Equalizing pulse	31,500	narrow pulse	master oscillator
Horizontal-synchronizing pulse	15,750	medium pulse	equalizing pulses selected by horizontal-pedestal modulator
Vertical synchronizing blocks	31,500	wide block	equalizing pulses
Horizontal pedestal	15,750	wide pulse	equalizing pulses (delayed)
Vertical blanking	60	wide pulse	60-cycle, 9-line keying
60-cycle, 9-line keying	60	medium pulse	frequency-divider chain
60-cycle, 3-line keying	60	narrow pulse	60-cycle, 9-line keying (delayed)

V. Signal-Synthesis Circuits

The synthesis of the composite television signal from the various components generated (Section IV) is done in several successive stages.

In a television synchronizing generator, uniform and precisely regular timing of the leading edges of the three components used to synchronize the horizontal-scanning system at successive time intervals is essential to the reproduction of a picture with straight vertical edges and tight horizontal synchronization. For example, if the leading edges of the equalizing pulses or the vertical-synchronizing blocks are delayed by but a microsecond relative to the uniform regularity of the horizontal-synchronizing pulses, a "tear" or horizontal displacement of several of the lines at the top of the picture may appear due to the transient disturbance set up in the receiver horizontal-scanning system. Thus, unusual precautions must be taken to insure leading-edge regularity between the various horizontal-synchronizing components.

It is, of course, possible to use adjustable delay circuits between the master timing signal and each of the three horizontal-synchronizing components, which can be individually adjusted to provide uniform timing. Such an arrangement would be subject to the variations in timing that might arise from nonuniform drifting of the time-delay circuits and to the component-generating circuits derived therefrom.

A more stable system not requiring any such critical adjustments for obtaining the exact timing of the leading edges of these various components has been successfully used. In this system, the leading edges of one reference timing signal are used directly for all components, and the various trailing edges corresponding to

the desired pulse widths are introduced by the signal-synthesis circuits. This may sound difficult, but it can be done fairly easily, as will be described in the following subsections.

The circuits required for synthesis are mostly modulators, mixers, and clippers. Various systems of modulation can be used, but the one found easiest to apply for these purposes is a type of grid modulation in which one signal is impressed on the grid of the modulator, and the other on its cathode. In some cases such modulation is accomplished by exciting the grids of two tubes with the signals to be intermodulated, and operating them with a common cathode load resistor. Mixing can be accomplished by simple addition, by paralleled-plate connections of two tubes with a common load resistor, or by paralleled-cathode connections. The method to be used in a particular case will depend on the polarity and wave form of the signals, and on any clipping that may be done simultaneously.

A. Assembly of the Horizontal-Synchronizing Signal

The leading edge of the equalizing-pulse signal has been selected as the time reference to be used as a part of all three horizontal-synchronizing components because it is the narrowest pulse and because it can be timed directly from the sine-wave master oscillator.

The circuits for assembling a horizontal-synchronizing signal from the leading edge of the equalizing-pulse signal and the trailing edge of the horizontal-synchronizing pulse signal as generated (Section IV *C*) are shown in Fig. 8. The synthesis of the composite pulse comprises adding the selected alternate equalizing pulses to the horizontal-synchronizing pulses as generated and thence clipping off the overlap.

B. Insertion of the Equalizing Pulses into the Horizontal-Synchronizing Signal

The newly assembled precision horizontal-synchronizing-pulse signal (from Section V *A*) is fed into a modulator. Here a gap of nine pulses is removed by the 60-cycle, 9-line keying signal, as shown in Fig. 11. The equalizing pulses are also fed into another modulator in which a group of eighteen pulses is selected by the 60-cycle, 9-line keying signal. The outputs of the

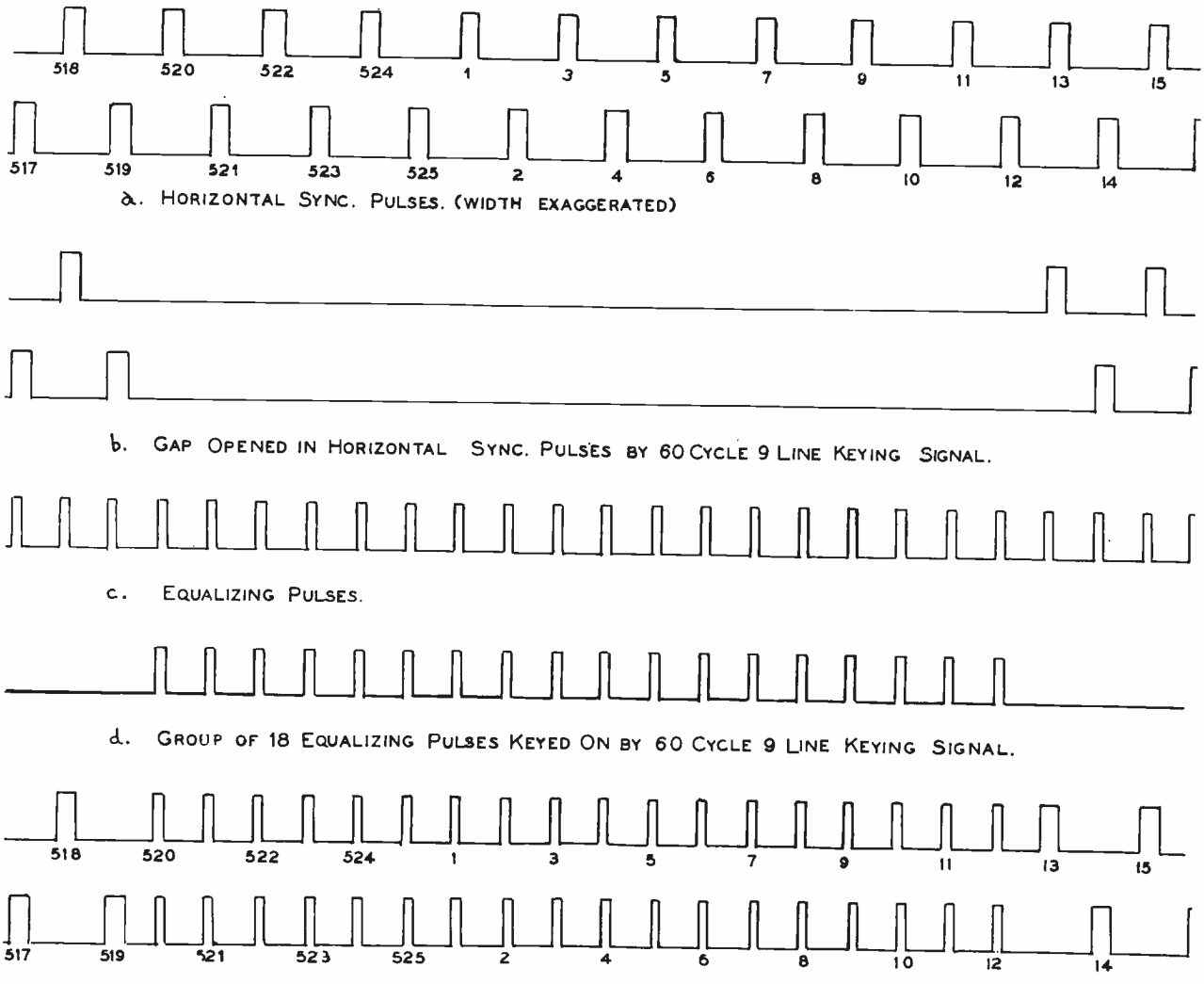
518 520 522 524 1 3 5 7 9 11 13 15
517 519 521 523 525 2 4 6 8 10 12 14
a. HORIZONTAL SYNC. PULSES. (WIDTH EXAGGERATED)
b. GAP OPENED IN HORIZONTAL SYNC. PULSES BY 60 CYCLE 9 LINE KEYING SIGNAL.
c. EQUALIZING PULSES.
d. GROUP OF 18 EQUALIZING PULSES KEYED ON BY 60 CYCLE 9 LINE KEYING SIGNAL.
518 520 522 524 1 3 5 7 9 11 13 15
517 519 521 523 525 2 4 6 8 10 12 14
PROPERLY INSERTED EQUALIZING PULSES. SIGNAL b ADDED TO SIGNAL d.

Fig. 11—Insertion of equalizing pulses into horizontal-synchronizing signal.

two modulators are mixed together, and clipped, to form a composite horizontal-synchronizing signal in which the normal train of horizontal-synchronizing pulses is interrupted at 60-cycle intervals by a group of eighteen equalizing pulses. The circuits are shown in Fig. 12.

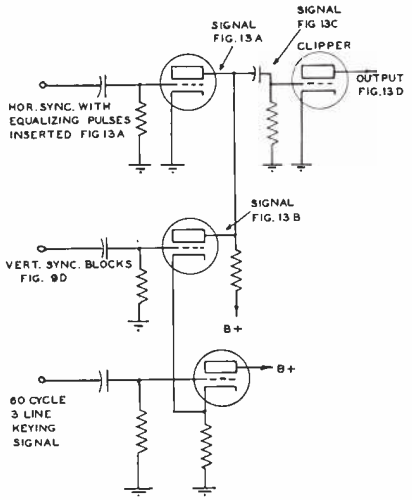

Fig. 12—Circuit of modulator for inserting equalizing pulses.

C. Insertion of the Vertical-Synchronizing Blocks

This same process of modulation is used in the next stage of the signal synthesis. Here, for exactly the center six equalizing pulses, the vertical-synchronizing blocks are added as shown in Figs. 13 and 14. The modulating

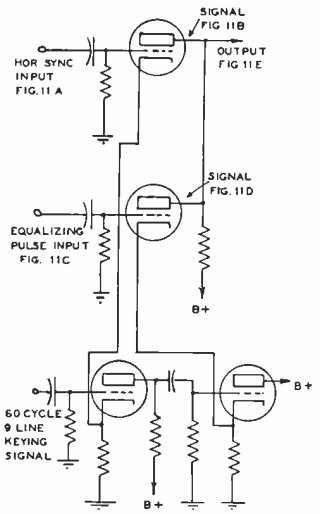

Fig. 14—Circuit of modulator for inserting the vertical-synchronizing blocks.

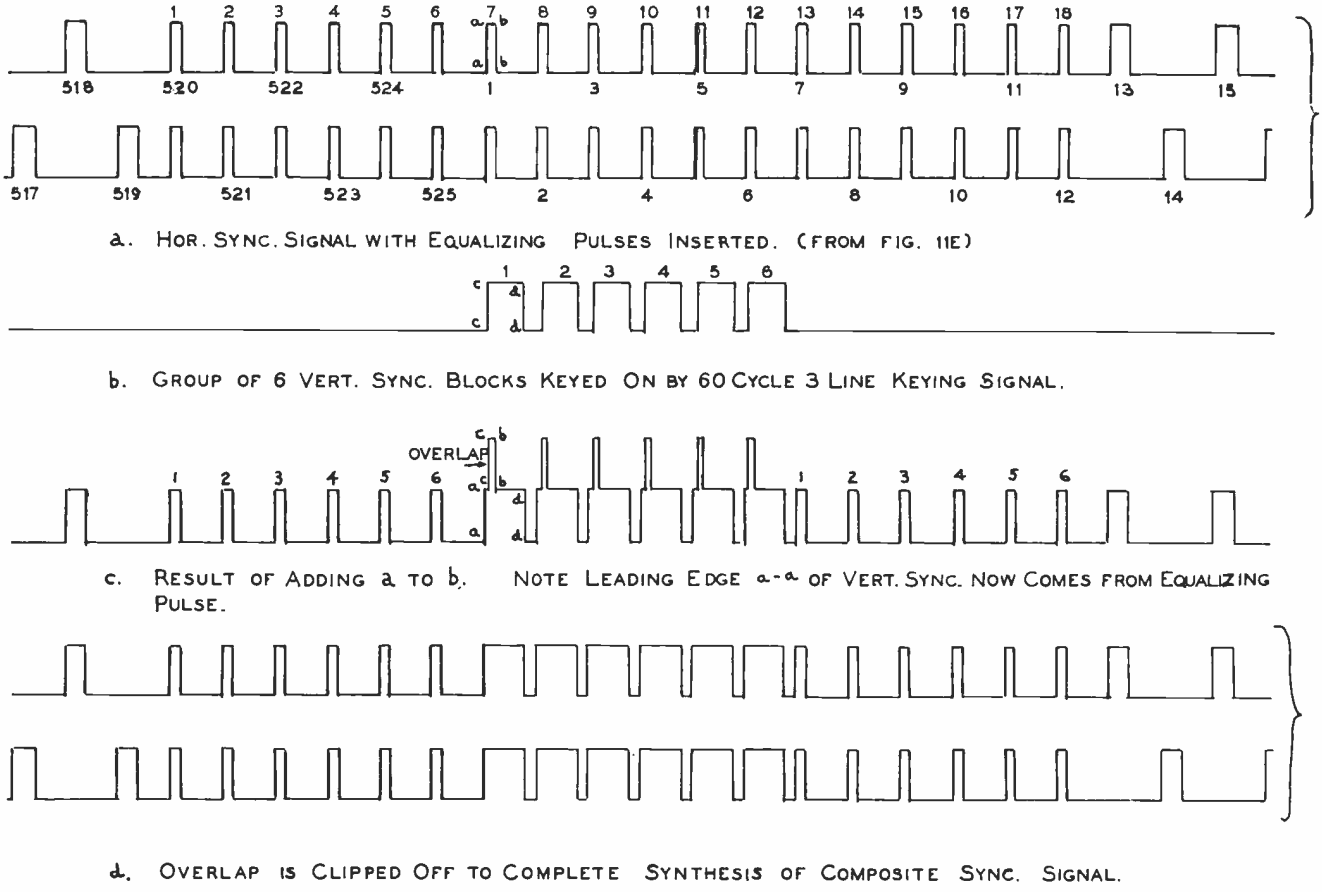
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
518 520 522 524 1 3 5 7 9 11 13 15
517 519 521 523 525 2 4 6 8 10 12 14
a. HOR. SYNC. SIGNAL WITH EQUALIZING PULSES INSERTED. (FROM FIG. 11E)
1 2 3 4 5 6
b. GROUP OF 6 VERT. SYNC. BLOCKS KEYED ON BY 60 CYCLE 3 LINE KEYING SIGNAL.
OVERLAP
1 2 3 4 5 6 1 2 3 4 5 6
c. RESULT OF ADDING a TO b. NOTE LEADING EDGE a-a OF VERT. SYNC. NOW COMES FROM EQUALIZING PULSE.
d. OVERLAP IS CLIPPED OFF TO COMPLETE SYNTHESIS OF COMPOSITE SYNC. SIGNAL.

Fig. 13—Insertion of the vertical-synchronizing blocks into the composite synchronizing signal.

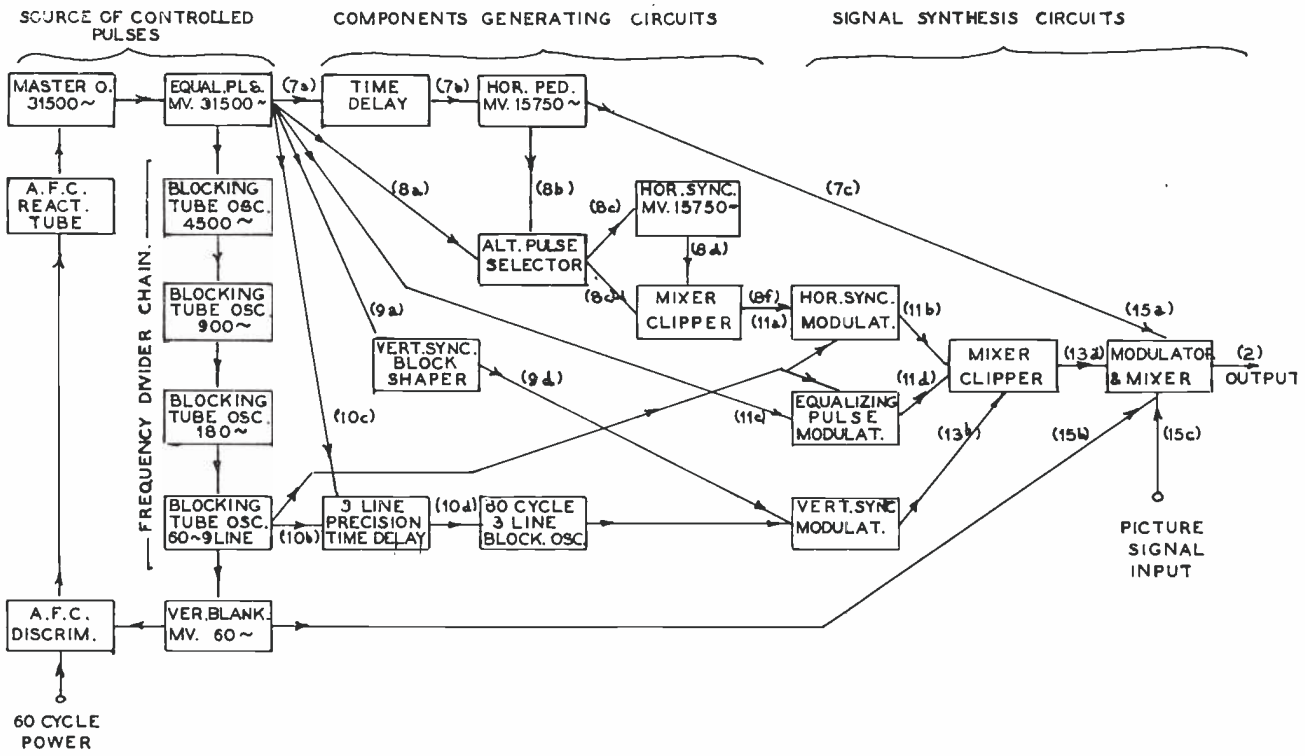

Fig. 16—Detailed block diagram of synchronizing generator. References in parentheses are to wave-form figures.

signal is the 60-cycle, 3-line keying signal, and the modulation process does not include interruption of the eighteen equalizing pulses, but merely the addition of the vertical-synchronizing blocks to the center six equalizing pulses. The resulting composite synchronizing signal is then clipped to remove the overlap existing between the center six equalizing pulses and the vertical-synchronizing blocks. By this process, once more, the leading edges of the equalizing pulses have been made to form the final leading edges of the vertical-synchronizing blocks, to complete the assembly of all three of the horizontal-synchronizing components from the same train of leading-edge signals.

D. Mixing the Picture and Pedestal Signals

The horizontal-pedestal signal is modulated by the vertical-blanking signal so as to blank it off during the vertical-retrace interval. The picture signal is then added to the horizontal-pedestal signal. The modulation and mixing circuits should be arranged to cut off the picture modulator during the horizontal- and vertical-blanking periods, so as to prevent spurious components

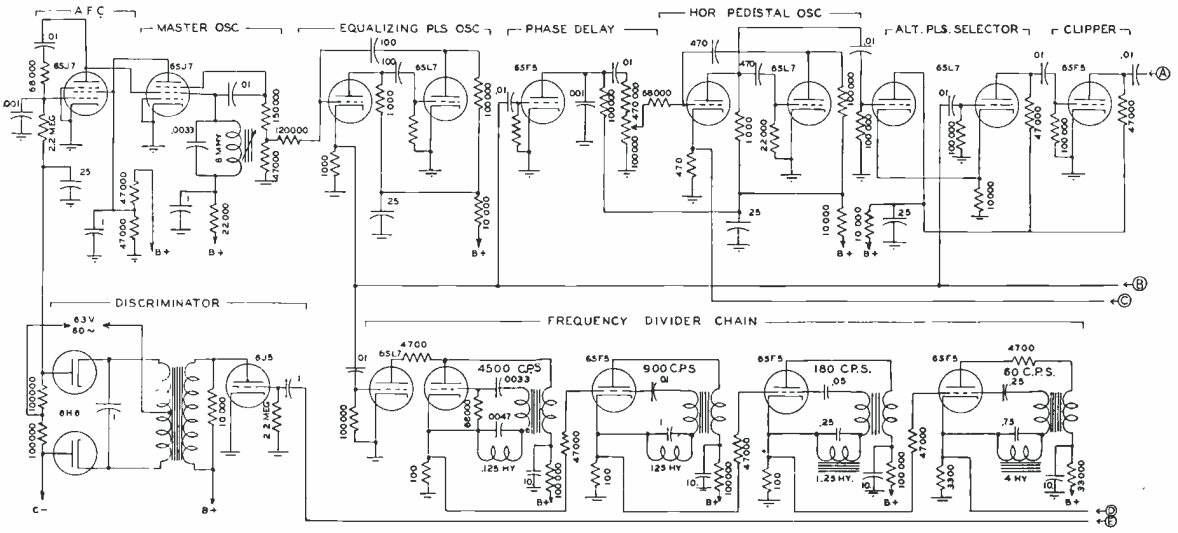

Fig. 17—Detailed schematic diagram of a television synchronizing generator.

of the picture signal occurring during these intervals from interfering with the synchronizing signals (see Fig. 15).

E. Final Stage: Adding the Composite Picture and Blanking Signal to the Composite Synchronizing Signal

These two composite signals can be mixed or simply added together to form the complete video signal suitable for radio transmission via ultra-high-frequency carrier. Television receivers used with such a signal should be properly designed to utilize the Federal Communications Commission standard television signal.

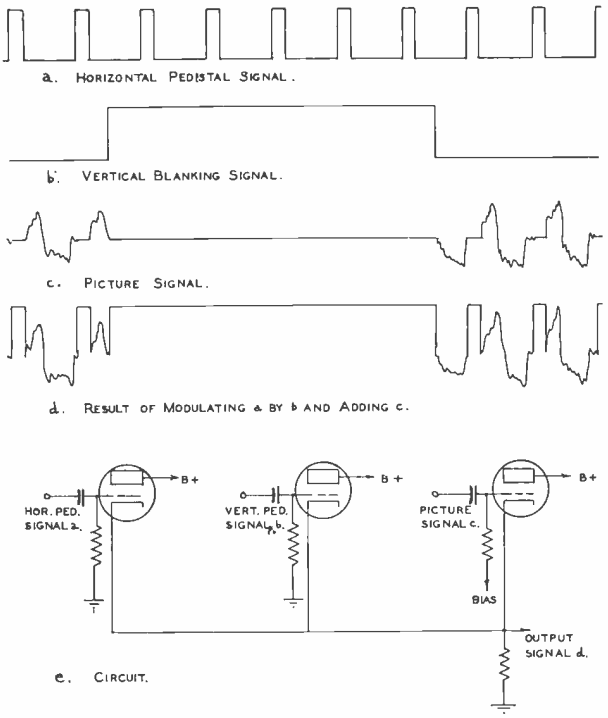

Fig. 15—Modulation of the horizontal pedestal by the vertical blanking signal and mixing with the picture signal.

VI. The Complete Synchronizing Generator

A block diagram and also a complete circuit schematic for a television synchronizing generator are shown in Figs. 16 and 17, respectively. Because it will seldom be possible for the experimenter to duplicate exactly all the conditions of an original working model, some variations in the values of the various electrical parameters can be expected.

A photograph of a television synchronizing generator made along the described lines is shown in Fig. 18. This particular unit was designed for the 441-line standard as formerly existed, and was used for some time as a part of a portable television demonstration unit. No controls, screwdriver operated or otherwise, were provided for the maintenance of the unit in proper adjustment, except for a vernier tuning capacitor in the master-oscillator tank circuit.

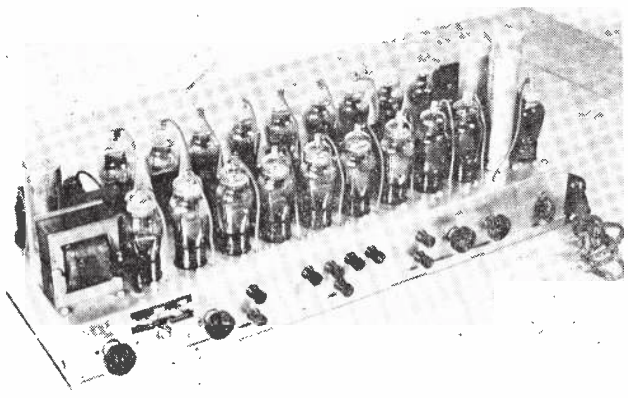

Fig. 18—Synchronizing generator for 441-line television.

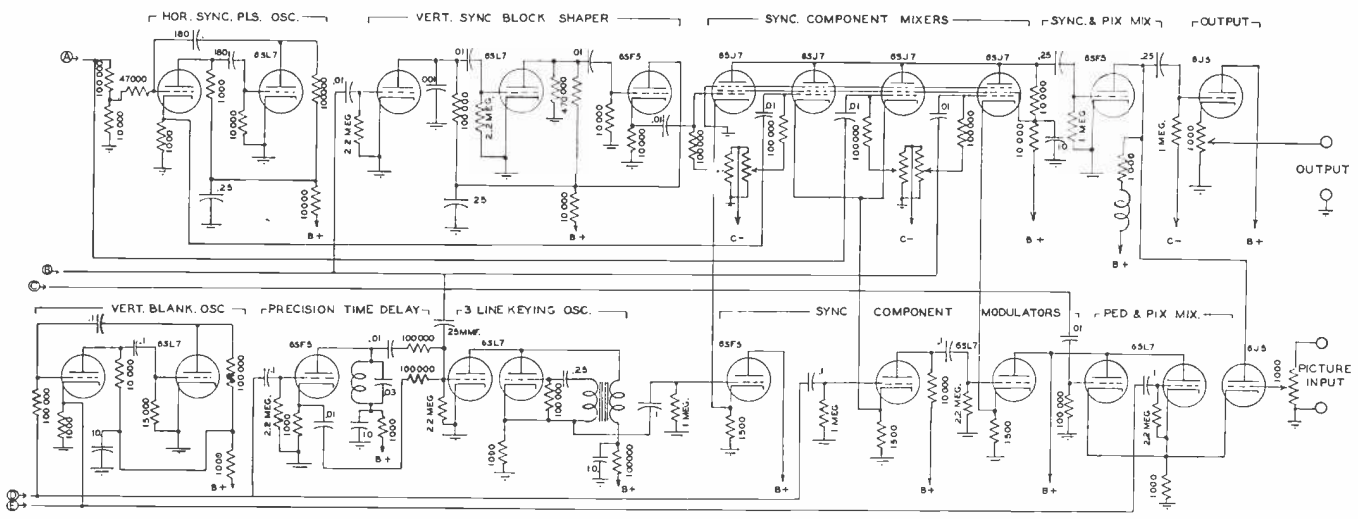

Fig. 17, continued. (A, B, C, D, and E indicate continuous lines.)

The Effect of Negative Voltage Feedback on Power-Supply Hum in Audio-Frequency Amplifiers*

GEOFFREY BUILDER†, FELLOW, I.R.E.

Summary—Some confusion exists regarding the effect of negative voltage feedback on the signal-to-hum ratio in the output of an audio-frequency amplifier. This appears to be due to lack of care in interpretation of the negative-feedback equations and to the application of these equations to circuit arrangements which do not conform to the conditions implied in their formulation. Various cases are discussed to illustrate the proper interpretation and application of the equations. The conclusions to be derived from these discussions may be summarized briefly as follows:

(1) Where the negative voltage feedback circuits satisfy the relevant conditions implied in the formulation of equations for simple negative feedback, the signal-to-hum ratio, for constant signal output, is improved by the gain-reduction factor $(1-\beta M)$.

(2) This improvement must be interpreted in relation to the complex value of the factor $(1-\beta M)$ and its variation with frequency, in relation to the frequencies of the signal and hum voltages.

(3) Failure to achieve the improvement in signal-to-hum ratio thus predicted may be due to the feedback voltage including voltage other than the fraction β of the output voltage required for simple negative feedback. A further specific analysis is then necessary to determine the effect of the feedback on the signal-to-hum ratio.

(4) In general, hum balancing within the amplifier is independent of the feedback only when the conditions for simple negative feedback are satisfied.

(5) Although, without feedback, it is legitimate to calculate the hum output voltage due to the high-tension hum voltage e by considering simple potential division of this voltage between the load impedance and the valve anode resistance R_a, this procedure is not generally valid when applied to an amplifier with feedback if the effective value of the anode impedance Z_a' of the valve is taken to be $R_a/(1-\mu\beta)$. This arises because Z_a' is the effective value of the valve impedance as viewed from the amplifier output terminals and is not necessarily significant when potential division of the voltage e is considered. It has, however, been shown in Section III(c) that, when the feedback voltage is proportional to $(e+e_0)$, the effect of the feedback on the hum output due to e is identical with that obtained on the basis of simple potential division, using the effective value Z_a'.

I. Introduction

NEGATIVE voltage feedback is commonly applied to audio-frequency amplifiers in radio receivers and similar equipment for reduction of nonlinear distortion and frequency discrimination in the amplifier itself or in its load circuit. The theory of negative feedback suggests that hum and other noise voltages introduced by the amplifier and its associated circuits should also be reduced. There is, however, some confusion as to what improvement in signal-to-hum ratio may, in fact, be expected from the application of negative feedback. This appears to arise from two main causes; lack of care in interpretation of the significance of the negative-feedback equations, and application of these equations to circuit arrangements which do not conform to the conditions implied.

* Decimal classification: R363.2×R263. Original manuscript received by the Institute, June 18, 1945.

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It is the object of the following discussion to clarify these points. The second of them arises from the fact that there is in common use[1–5] a number of negative-feedback circuits that do not conform to the conditions implied in the negative-feedback equations formulated by Black.[6] The term "simple negative feedback" will be used to distinguish circuit arrangements conforming to Black's implied condition that the feedback voltage should be a definite fraction of the output voltage and should not include any other voltages. For simplicity, attention is restricted to the use of negative voltage feedback, and the discussion is illustrated by circuit arrangements typical of its application; but it is obvious that similar considerations might arise in the application of other types of feedback.

The symbols and abbreviations used in the text are summarized below for convenient reference:

M = voltage gain of an amplifier or valve (vacuum tube), measured between the input and output terminals.

M_s = voltage gain from the screen grid to anode of a pentode valve.

μ = amplification factor of the amplifier or valve between input and output terminals.

μ_s = amplification factor of a pentode valve, from screen grid to anode.

β = that fraction of the output voltage fed back to the input circuit of the amplifier.

R_a = alternating-current anode resistance of the output valve of an amplifier.

Z_a = output impedance of the amplifier.

Z = load impedance into which the amplifier works.

e = hum voltage across the output of the high-tension rectifier filter supplying the amplifier.

e_i = an equivalent hum voltage referred to the input terminals of the amplifier and arising from sources within the amplifier *from which the hum is independent of the signal level.*

e_0 = output hum voltage developed across the amplifier output circuit.

e_0' = corresponding output hum voltage when simple

[1] Laboratory staff of Amalgamated Wireless Valve Company, "Negative feedback in R-C amplifiers," *Wirless World*, vol. 43, pp. 437–438; November 17, 1938.

[2] Amalgamated Wireless Valve Company, "Inverse feedback," *Radio Rev. Australia*, vol. 5, p. 64; March, 1937.

[3] G. Robert Mezger, "Feedback amplifier for C.R. oscilloscopes," *Electronics*, vol. 17, pp. 126–131, 254; April, 1944.

[4] F. Langford-Smith, "Radiotron Designer's Handbook," Wireless Press, Sydney, Australia, 1940, pp. 40–45. Complete reproduction, RCA Manufacturing Company, Harrison, N. J.

[5] F. Langford-Smith, "The relationship between the power output stage and the loudspeaker," *Proc. World Radio Convention*, Sydney, Australia, 1938.

[6] H. S. Black, "Stabilized feedback amplifiers," *Bell. Sys. Tech. Jour.*, vol. 13, pp. 1–19; January, 1934.

negative voltage feedback is applied to the amplifier.

e_0'' = corresponding output hum voltage when feedback, other than simple negative feedback, is applied to the amplifier.

In each case, the suffixes t and p are used for amplifiers having the output valve connected as a triode or pentode, respectively.

The amplification factor μ is defined by

$$(de_a/de_g) \text{ for } i_a \text{ constant}$$

where e_a is the anode voltage of the output valve, e_g the potential of the input control grid, and i_a the anode current of the output valve. For a single valve μ is real and negative, in agreement with the actual physical value of the amplification factor. In any case, the sign of μ is consistent with that of M, and in the case of a single valve, corresponds to the change of phase of 180 degrees (for resistive load) between input and output voltages.

II. Simple Negative Voltage Feedback

The general theory and equations of simple negative voltage feedback are well known; but, for clarity, those equations relevant to the discussion will be set out briefly in convenient form. In deriving these equations it is implied that the feedback voltage is derived from, and is directly proportional to, the voltage developed across the amplifier output terminals.

If the voltage gain of an amplifier without feedback is M, and if a *fraction β of the voltage across the output circuit* is fed back to the amplifier input in series with the signal voltage, the gain becomes

$$M' = M/(1 - \beta M) \tag{1}$$

and the quantity $(1-\beta M)$ is conveniently referred to as the gain-reduction factor. The gain M is related to the amplification factor μ of the amplifier, the load Z, and the anode resistance R_a of the output valve, by

$$M = \mu \cdot Z/(Z + R_a). \tag{2}$$

The effect of the feedback on the output impedance of the amplifier is to reduce it, from the anode resistance R_a of the output valve, to a value Z_a' (which will in general have a complex value) given by

$$Z_a' = R_a/(1 - \beta\mu). \tag{3}$$

It is to be noted that μ is always greater than M, and may be much greater when a pentode valve is used, so that the output impedance is reduced by a factor correspondingly greater than the gain-reduction factor.

It can be shown readily that distortion, hum, and noise voltages generated in the amplifier and its associated circuits and *developed across the output circuit* are also reduced by the gain-reduction factor $(1-\beta M)$. When, as is usually the case, the signal input voltage is increased by the factor $(1-\beta M)$ to maintain the signal output at the same level as without feedback, one might expect an improvement in the signal-to-hum and signal-to-distortion ratios across the output circuit by the factor $(1-\beta M)$, insofar as the hum or distortion originates within the amplifier.

These equations are valid for all real and complex values of the parameters μ, M, β, and Z, and the value of the gain reduction factor $(1-\beta M)$ is generally complex and dependent on frequency even for a single-valve amplifier; some of the advantages of negative feedback are in fact due to this.

It is obvious that great care is required to ascertain the exact significance of "an improvement in signal-to-hum ratio by the gain-reduction factor $(1-\beta M)$." An analysis can readily be made for any specific case, and it is clear that the reduction of signal-to-hum ratio must depend on the relative frequencies of the signal and hum voltages; only when the frequencies are identical will the gain-reduction factor be the same for both. It is not unusual to refer to an amplifier having negative feedback giving a gain reduction stated in decibels; the reference is usually to the numerical value of the gain-reduction factor at the center of the transmitted band and the gain-reduction factor at the hum frequency may be very much less, and may even in some cases be less than unity.

Proper application of the theory thus permits a correct assessment of the improvement to be expected in signal-to-hum ratio from the use of negative voltage feedback. Failure to achieve this in practice may be due to the use of feedback circuits that fail to satisfy the conditions implied. One departure from these conditions occurs when the voltage fed back includes voltages other than the fraction β of the amplifier output voltage. In practice, this probably occurs most often if the output valve of the amplifier is transformer-coupled to the load and is series fed, and if the feedback voltage is taken from between anode and cathode of the output valve; the voltage fed back then includes some fraction of any hum voltage in the high-tension supply to the output valve.[1-5]

III. Amplifier with Transformer Coupling to the Load

Transformer coupling is sometimes used for voltage amplification but is chiefly of interest in radio-receiver design for coupling the amplifier power output to a load. For illustration, an amplifier using a series-fed output valve transformer-coupled to the load, and operated under class A conditions, will be considered.

Such an amplifier may use either a pentode or triode output valve. For immediate comparison of the two types it is convenient to consider the same pentode (or beam-power) amplifier valve connected as a triode or pentode. Denoting its anode resistance as a pentode by R_{ap} and as a triode by R_{at}, we have the approximate relation

$$R_{ap} = \mu_s \cdot R_{at} \tag{4}$$

where μ_s is the amplification factor from screen grid to anode. Typical series-fed power-amplifier circuits are shown in Fig. 1. In Fig. 1(a) the output valve is triode-connected and works into a load Z_t presented to it by the output transformer, while in Fig. 1(b), the output valve is pentode-connected and works into a load Z_p. In each case, the anode is fed from a high-tension source with output filter L, C; the impedance of C to hum and signal voltages will be neglected in comparison with the load impedance. Bias arrangements are not shown but are also assumed to have negligible impedance at signal and hum frequencies. Although a single-valve amplifier is depicted in Fig. 1 for purposes of illustration, the ensuing discussion must be taken to be equally applicable to a multistage amplifier.

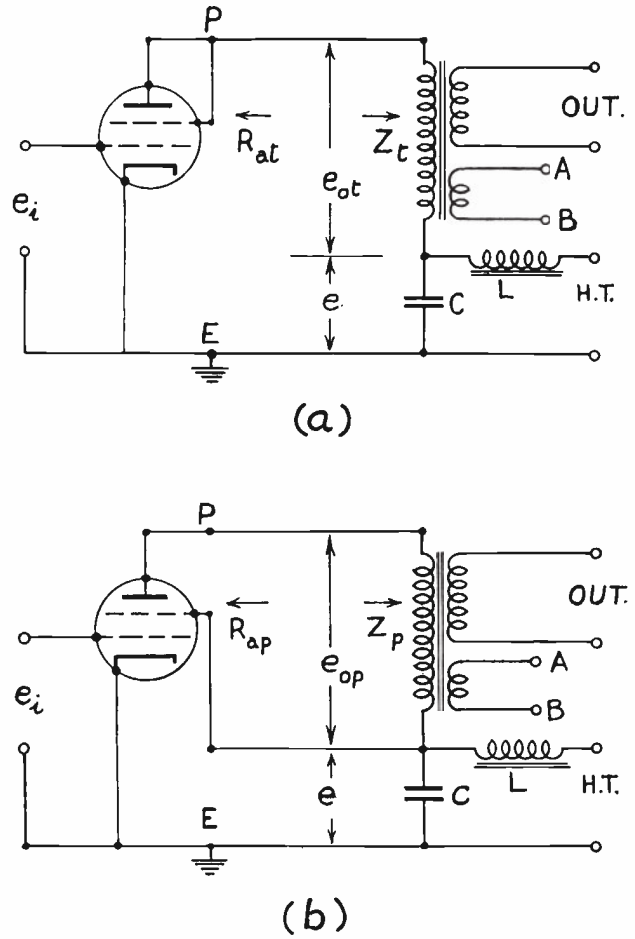

Fig. 1—Series-fed transformer-coupled amplifier (a) triode connection (b) pentode connection.

The hum voltage across the filter capacitor C is denoted by e. Hum arising from other sources within the amplifier is represented by an equivalent hum voltage e_i applied to the input terminals in series with the signal input voltage, and it is assumed that e_i is independent of the signal voltage. It is clear that, should the signal voltage itself include hum voltages, the signal-to-hum ratio in the amplifier output, insofar as it is due to hum from the signal source, will not be affected by the application of negative feedback to the amplifier except insofar as the gain-reduction factor is frequency-dependent and the signal and hum frequencies are different; that is to say, insofar as the frequency-response characteristic of the amplifier is affected by the feedback.

(a) Hum Output Without Feedback

The hum voltage developed across the output circuit is readily calculated. For the triode we have

$$e_{0t} = -Z_t \cdot e/(Z_t + R_{at}) + M_t \cdot e_i \qquad (5)$$

where M_t is the voltage gain from grid to anode, and is given by

$$M_t = Z_t \cdot \mu_t/(Z_t + R_{at}).$$

The first term of (5) corresponds to simple potential division of the hum voltage e between the load and anode impedances, while the second represents the amplification of the equivalent hum voltage e_i referred to the amplifier input circuit.

For the pentode, account must also be taken of the hum voltage e applied to the screen grid, and the output ripple voltage is given by

$$e_{0p} = -Z_p \cdot e/(Z_p + R_{ap}) + M_s \cdot e + M_p \cdot e_i \qquad (6)$$

where M_p is the voltage gain from grid to anode and M_s that from screen grid to anode, and

$$M_p = Z_p \cdot \mu_p/(Z_p + R_{ap}) \qquad M_s = Z_p \cdot \mu_s/(Z_p + R_{ap}).$$

Comparison of (5) and (6), taking into account (4), indicates that the hum output voltage for a pentode, arising from the hum voltage e applied to its anode and screen circuits, will usually exceed the corresponding output hum voltage for the triode owing to the magnitude of the term $M_s e$. For example, the beam-power valve type 6V6G has the typical operating conditions.

$R_{at} = 2500$ ohms	$R_{ap} = 50{,}000$ ohms
$Z_t = 4000$ ohms	$Z_p = 5000$ ohms
$\mu_s = -20$	$M_s = -1.8$

and (5) and (6) give the respective hum output voltages

$$e_{0t} = -0.6e \qquad e_{0p} = -1.7e.$$

Such a comparison will, of course, apply only when series feed is used and the screen supply includes the hum voltage e. If the screen supply is further filtered to such an extent that the hum voltage applied to the screen is negligible, the output hum voltage due to e is determined by the first term of (6) and will be considerably less than in the case of the triode, owing to the large value of the anode resistance R_{ap} in comparison with the load impedance.

(b) The Effect of Simple Negative Feedback on the Hum Output Voltage

The application of simple negative voltage feedback to the amplifier, as defined in Section II, requires that the voltage fed back be a fraction of the voltage developed across the output load circuit; i.e., across Z_t or Z_p. This condition is most readily satisfied by taking the feedback voltage across an appropriate winding AB on the output transformer as indicated in

Fig. 1. When this is done, the hum output voltage is reduced by the factor $(1-\beta M)$. We then have, for the triode and pentode connections, respectively,

$$e_{0t}' = e_{0t}/(1 - \beta M_t) \quad (7)$$

$$e_{0p}' = e_{0p}/(1 - \beta M_p). \quad (8)$$

These expressions cannot be formulated in terms of the reduction in effective output impedance Z_a' of the amplifier because the voltage e is not included in the feedback and the effective output impedance Z_a' is not applicable to such a calculation; i.e., it is not the effective impedance as viewed from the terminals of the voltage e.

It is obvious that, in this case, the reduction in the hum output voltages occurs equally for hum from the various sources and any hum balancing within the amplifier will not be affected by the feedback. However, if the output transformer feeds a moving-coil loudspeaker of which the field coil is used for smoothing the rectified high-tension supply to the amplifier, the speaker may have a hum-balancing coil wound over the field coil and connected in series with the voice coil. In general, a hum voltage will then be produced across the transformer secondary and reduction of this voltage by the feedback may require compensation by adjustment of the hum-balancing coil.

(c) The Effect of Other Feedback Circuits on the Hum Output Voltage

It is a common, and undoubtedly convenient, practice to utilize a feedback voltage other than that required for simple negative feedback as specified in Section II above. Among the most common of such modified circuits is that in which the feedback voltage is obtained by potential division from the anode-cathode voltage of the output amplifier; i.e., the voltage between points P and E in Figs. 1(a) and 1(b). This arrangement departs from the simple feedback circuit in that the feedback voltage is a fraction, not of the output load voltage, but of the output voltage plus the hum voltage e across the capacitor C. It is not, therefore, to be expected that the modification of the hum output voltage indicated by the theory of simple feedback will occur.

If the output valve is triode-connected, the effect of this feedback circuit will be to change the output hum voltage from its value e_{0t} without feedback (equation (5)), to a value e_{0t}'' given by

$$e_{0t}'' = -Z_t \cdot e/(Z_t + Z_{at}') + M_t' \cdot e_i \quad (9)$$

where

$$Z_{at}' = R_{at}/(1 - \beta\mu_t).$$

$$M_t' = M_t/(1 - \beta M_t)$$

and for large amounts of feedback this approximates to

$$e_{0t}'' = -e + M_t' \cdot e_i \quad (10)$$

indicating that, owing to the reduction in the effective output impedance of the amplifier by the feedback, practically the whole of the hum voltage e is developed across the load; but that hum voltages represented by e_i are reduced by the gain-reduction factor. It happens in this case, because the feedback voltage is proportional to $(e+e_0)$, that the effect of the feedback on the hum due to e can be expressed in terms of the change in effective output impedance of the amplifier.

If the output valve is pentode connected, the effect of this feedback arrangement will be to change the hum voltage output from its value e_{0p} without feedback, as given in (6), to a value e_{0p}'' given by

$$e_{0p}'' = -Z_p \cdot e/(Z_p + Z_{ap}') + M_s' \cdot e + M_p' \cdot e_i \quad (11)$$

where

$$Z_{ap}' = R_{ap}/(1 - \beta\mu_p)$$

$$M_s' = M_s/(1 - \beta M_p)$$

$$M_p' = M_p/(1 - \beta M_p).$$

Without feedback, the first term of (11) is small but increases to the limiting value $-e$ for large values of feedback, as in the case of the triode. The hum arising in the screen and input circuits is decreased by the gain-reduction factor.

(d) Hum Balancing

For either connection of the output valve, the net result of the feedback on the total output hum depends on the relative phases and amplitudes of the various hum voltages. Equations (5), (6), (9), and (11) state the conditions necessary for reduction of the output hum voltage to zero by any process of hum-balancing within the amplifier such as those described[7,8] in the literature. It is to be noted that any such balance generally depends on the degree and nature of the feedback, but that *when the conditions for simple negative feedback are satisfied, the balance is independent of the feedback*, as indicated by the form of (7) and (8).

IV. Other Amplifiers

In amplifiers having an output circuit other than the series-fed transformer arrangement discussed in relation to Fig. 1, the output voltage is usually identical with the anode-to-cathode voltage of the output valve, and the relevant conditions for simple negative feedback are satisfied by almost any convenient circuit arrangement. This applies, for example, to a parallel-fed transformer-coupled output circuit, or to a resistance- or choke-coupled voltage amplifier. Simplified circuits corresponding to these cases are shown in Figs. 2(a) and 2(b) and can be used to represent a wide range of practical cases.

In Fig. 2 the high-tension supply is fed to the amplifier anode through an impedance Z_1 which may be a

[7] Wen-Yuan Pan, "Circuit for neutralizing low-frequency regeneration and power-supply hum," Proc. I.R.E., vol. 30, pp. 411–412; September, 1942.

[8] K. B. Gonser, "A method of neutralizing hum and feedback caused by variations in the plate supply," Proc. I.R.E., vol. 26, pp. 442–449; April, 1938.

resistance (e.g., resistance-capacitance-coupled voltage amplifier) or a choke (e.g., parallel-fed transformer-coupled amplifier). The anode of the valve is coupled through a blocking capacitor to a load Z_2 which may be the grid leak of a succeeding stage, or may be presented

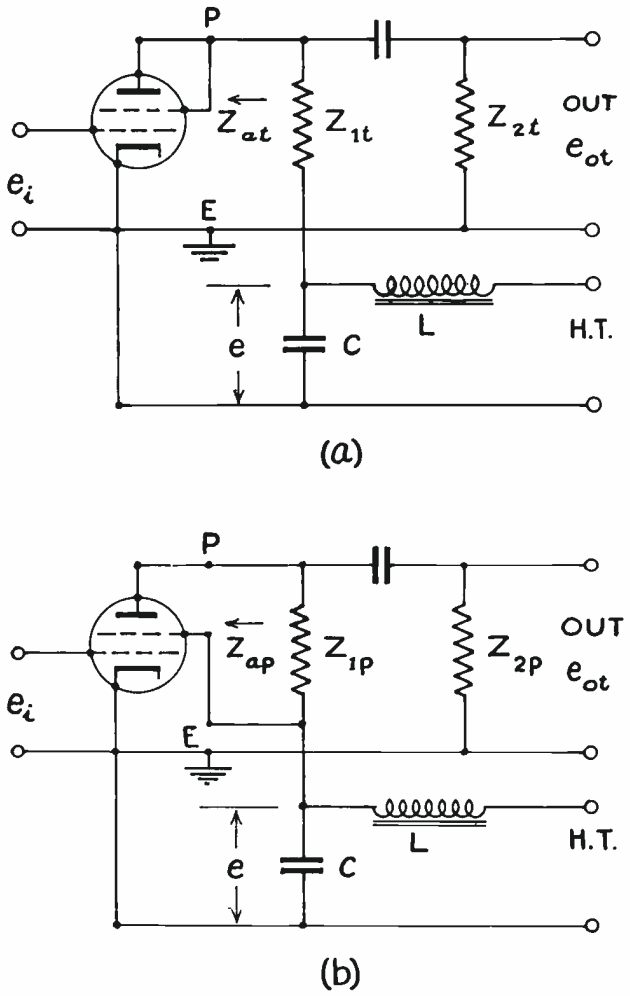

Fig. 2—Parallel-fed amplifier (a) triode connection (b) pentode connection.

by the primary of an output transformer. In Fig. 2(a) the output valve is triode-connected, and in Fig. 2(b), pentode-connected. In each case the hum and signal voltages applied are the same as in the foregoing discussion.

Without feedback, the hum output voltage may readily be shown to be, for the triode and pentode connections respectively,

$$e_{0t}=\frac{-R_{at}\cdot Z_{2t}}{R_{at}\cdot Z_{2t}+R_{at}Z_{1t}+Z_{1t}\cdot Z_{2t}}\cdot e+M_t\cdot e_i \qquad (12a)$$

$$e_{0p}=\frac{-R_{ap}\cdot Z_{2p}}{R_{ap}\cdot Z_{2p}+R_{ap}\cdot Z_{1p}+Z_{1p}\cdot Z_{2p}}\cdot e+M_s\cdot e+M_p\cdot e_i \qquad (12b)$$

where

$$Z = Z_1\cdot Z_2/(Z_1+Z_2)$$
$$M = Z\cdot\mu/(Z+R_a)$$
$$M_s = Z\cdot\mu_s/(Z+R_a)$$

and the subscripts t and p refer to the triode and pentode connection respectively. Z, M, and M_s have the same significance as in the cases discussed previously. In (12a) and (12b) the first term represents simple potential division of the hum voltage e between the feed impedance Z_1 and the load Z_2 in parallel with the anode resistance R_a of the valve. It is clear that the hum output voltage will, in general, in the case of parallel feed be less for a triode, but greater for a pentode, than in the case of series feed.

Negative voltage feedback may be provided by simple potential division of the anode-cathode voltage of the valve or from a winding on an output transformer. In any straightforward method, the feedback voltage will be proportional to the amplifier output voltage, because this is identical with the anode-cathode voltage and the conditions for *simple negative feedback* are satisfied. The effect of the negative voltage feedback is, therefore, to reduce the hum output voltage from all sources by the gain-reduction factor. As in the case discussed in Section III(b) above, the effect of the feedback on the hum output voltage due to e, as given by the first term of (12), cannot be formulated in terms of the change in effective output impedance Z_a' of the amplifier with feedback, because the impedance Z_a' is the effective output impedance viewed from the output terminals and is not significant for the purpose of considering potential division of the hum voltage e.

Because the feedback satisfies our definition of *simple negative feedback*, hum-balancing arrangements within the amplifier are unaffected by the feedback. Hum across the load due to a loudspeaker hum-balancing coil can be treated as part of the hum output voltage Me_i and is reduced by the gain-reduction factor; some readjustment of the hum-balancing arrangement in the loudspeaker will be necessary.

V. Acknowledgment

I am deeply indebted to Mr. F. Langford-Smith for his interest and assistance in the preparation of this paper.

High-Voltage Rectified Power Supply Using Fractional-Mu Radio-Frequency Oscillator*

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Summary—**An oscillator circuit designed to operate with a vacuum tube having a small fractional mu has been used to develop across its grid-leak resistor a bias voltage whose value is over ten times as great as the anode-supply voltage. The principle can be demonstrated by connecting a triode so that its grid and anode are interchanged. However, special tubes of unconventional design were constructed for generating several thousand volts. The rectified voltage is negative in polarity relative to cathode, and thus is adapted for oscilloscopes. A slight modification permits a positive-polarity voltage to be obtained for use with television-picture tubes.**

THE PURPOSE of this paper is to describe a novel electronic system of producing direct-current voltages of the order of a few thousand volts from a lower direct-current voltage by means of a single vacuum tube. The system has application as a voltage source for high-impedance devices, such as cathode-ray tubes. The system, like that described by Schade (see bibliography), utilizes radio frequencies and thus has the advantage that low-capacitance filter capacitors may be employed with consequent reduction of shock hazards.

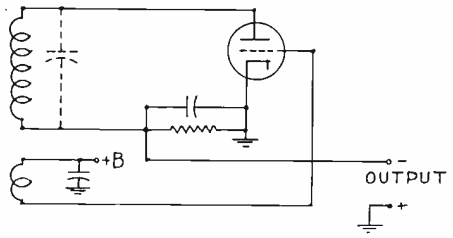

Fig. 1—Fractional-mu oscillator using conventional triode.

The circuit, in general, is that of a vacuum-tube oscillator with self-biased grid. During operation a negative potential is built up across the grid capacitor by electrons which the grid collects during the positive excursions of the grid-voltage swing. If the tube has certain characteristics, it is possible to build up a grid bias voltage which is many times greater than the direct-current voltage applied to the anode of the tube. This grid bias voltage constitutes the high-voltage direct-current output.

Consideration of the characteristics which an oscillator tube and associated circuit must have in order to build up a high bias voltage indicate that the oscillator circuit should have a large voltage step-up ratio from anode to grid, and the amplification factor or mu of the tube should be fractional; that is, less than unity. In order for oscillations to build up, the transconductance of the tube at small grid voltages should exceed the total circuit conductance.

* Decimal classification: R356.1×R388. Original manuscript received by the Institute, June 19, 1945. Presented, 1945 Winter Technical Meeting, New York, N. Y., January 26, 1945.

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In Fig. 1 is shown a fractional-mu oscillator circuit using a conventional triode. The grid of the tube is here connected to a direct-current source and acts as the oscillator anode, whereas the plate of the tube is connected to a high-impedance tank circuit and acts as the grid or control element of the oscillator. The control-electrode bias voltage which is built up across the parallel control-electrode resistor and capacitor constitutes the stepped-up direct-current output voltage. Tests on the circuit proved that a direct-current output voltage greater than the direct-current input could be obtained. However, it was found that a conventional tube was not practicable for high-voltage output, since the direct-current input voltage had to be kept quite low to avoid overheating of the grid structure in the tube.

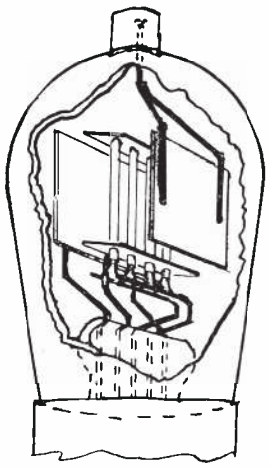

Fig. 2—Sketch of fractional-mu tubes A and B.

The next step was to design a fractional-mu tube which could stand direct-current input voltages of the order of 300 volts without overheating the anode. One such design is shown in Fig. 2. On both sides of an array of cylindrical cathodes are placed flat plates, one of which serves as the anode and the other as the control electrode.

The cross section and control-electrode-voltage-versus-anode-current characteristics of this tube are shown in Fig. 3. These curves show that this tube has a very remote cutoff characteristic which caused the tube to operate poorly as an oscillator. The prolonged tail on the curve is produced by uncontrolled emission from that part of the cathode surface facing the anode. The electric field produced at the cathode by the control electrode is greatest at that portion of the cathode facing the control electrode and is quite weak at the portion of the cathode facing the anode. Conversely, the electric field produced at the cathode by the anode is strongest

at that portion of the cathode facing the anode and is weak on the opposite side of the cathode. These two effects combined give the poor cutoff characteristic in Fig. 3.

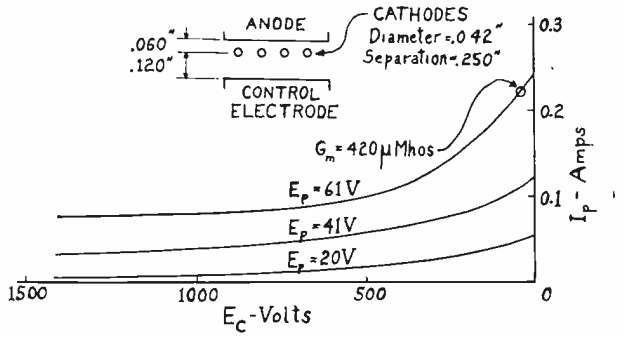

Fig. 3—Dimensions and characteristics of fractional-mu tube A. Cathodes are completely coated with oxide emitter. At $E_p=60$ volts and $I_p=0.10$ ampere, $\mu=0.046$. At $E_p=60$ volts and $I_p=0.15$ ampere, $\mu=0.060$.

In order to improve the cutoff, a similar tube was constructed in which the cathode coating extended only halfway around each cathode cylinder and faced the control electrode. The cross section and characteristics of this tube are shown in Fig. 4, wherein a substantial

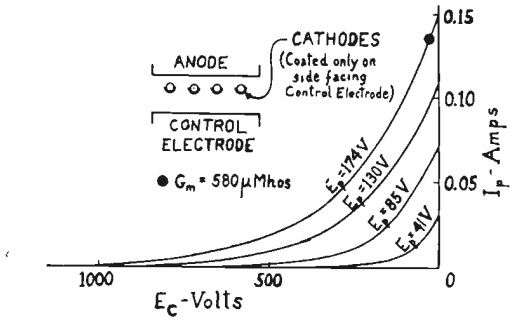

Fig. 4—Dimensions and characteristics of fractional-mu tube B. Cathodes are coated only on side facing control electrode. Dimensions are the same as tube A. At $E_p=107$ volts and $I_p=0.05$ ampere, $\mu=0.39$. At $E_p=152$ volts and $I_p=0.10$ ampere, $\mu=0.56$.

improvement in cutoff is indicated. The transconductance shows improvement, although the active cathode area has been decreased to one half. The mu of the tube was increased about fourfold by this change.

The performance of this tube as a fractional-mu oscillator was measured using the circuit shown in the Fig. 5, which oscillates at 190 kilocycles.

The details of the radio-frequency coil are shown in Fig. 6. This shows a cross-sectional view of the transformer, the axis of the coil being vertical. The secondary-to-primary turns ratio is 13. The coupling coefficient and Q are made fairly large by using an iron-dust core and Litz wire for the windings.

The performance data obtained with this tube and circuit are shown in Table I. The direct voltage developed across a 23-megohm resistor was from 14 to 17 times as great as the direct voltage applied to the anode of the oscillator tube. If the efficiency of the circuit is defined as the ratio of the power absorbed in the output resistor to the power input to the anode, the values shown in the extreme right-hand column are representative.

The fractional-mu oscillator tube with partly coated cathodes as in Fig. 4 made rather inefficient use of cathode heating power, since only one half of the cathode sleeve is coated with emitter and the remaining half

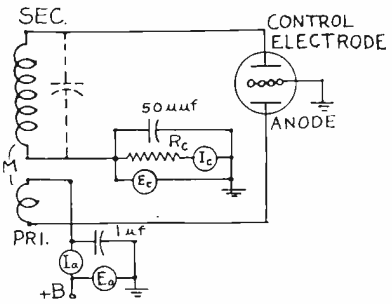

Fig. 5—Oscillator circuit for tube B.

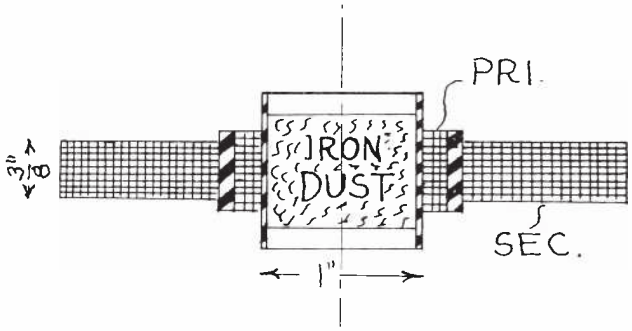

Fig. 6—Details of coil used in circuit of Fig. 5. Primary, next to core, is universal wound with 60 turns of 7/41 Litz wire; inductance = 220 microhenries. Secondary, insulated by $\frac{1}{8}$-inch-thick layer of varnished cambric, is universal wound with 780 turns of 7/41 Litz wire; inductance = 36 millihenries. The Q of the secondary measures 75 at 125 kilocycles. The coefficient of coupling = 0.5.

absorbs just as much cathode power but produces no emission. An improved design of fractional-mu oscillator tube which makes use of the entire cathode area is shown in Fig. 7. The control-electrode-voltage versus anode-

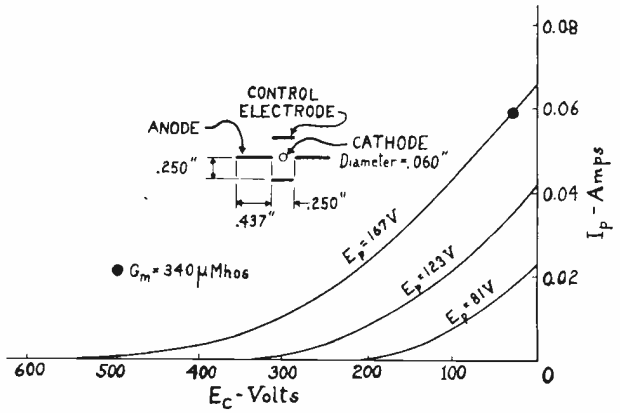

Fig. 7—Dimensions and characteristics of fractional-mu tube of improved design which uses a completely coated cathode.

current characteristic of this tube, shown in Fig. 7, is comparable with that of the preceding tube, and shows further improvement in cutoff. This tube was tested in

TABLE I
PERFORMANCE AF TUBE B IN CIRCUIT OF FIG. 5.

E_a Volts	E_c Volts	I_a Milli-amperes	I_c Milli-amperes	R_c Megohms	E_c/E_a	E_cI_c/E_aI_a
220	3160	14.7	0.134	23.6	14.4	0.13
312	4900	21.5	0.208	23.6	15.7	0.152
362	5900	25.5	0.250	23.6	16.3	0.16
490	8400	35.2	0.355	23.6	17.2	0.171
300	4540	25.0	0.360	12.6	12.0	0.217
485	7750	43.0	0.617	12.6	12.6	0.228

the circuit of Fig. 4 and gave substantially the same performance as the previous tube.

The output voltage developed across the control-electrode resistor and capacitor has considerable sawtooth component. Increasing the time constant will reduce this component to some extent, but a time constant will ultimately be reached where the oscillator will intermittently block. Thus, an additional resistance-capacitance filter is used preferably between the control-electrode resistor and the utilization device.

The potential derived is negative with respect to chassis and is thus of correct polarity for cathode-ray tubes used as oscilloscopes. In such applications the second anode and deflector plates are usually at chasis potential and the cathode at a large negative potential.

In television receivers it is most convenient to apply a large positive potential to the second anode while maintaining the cathode and grid near chasis potential. This permits simplified coupling between the last video stage and the cathode-ray-tube grid. It is possible, however, to connect the picture tube so that its cathode and grid are highly negative. However, a high-voltage capacitor and a direct-current reinsertion diode are necessary to couple the last video stage to the cathode-ray-tube grid.

If the cathode-ray tube is to be operated with its grid and cathode near chassis potential, the fractional-mu oscillator can be operated with the chassis connection at the negative-potential end of the grid resistor instead of at the cathode end. A separate low-wattage power supply operating above chassis potential can be used to supply the anode voltage and heater voltage for the fractional-mu tube. This supply will fluctuate in potential above chassis by an amount equal to the ripple present across the grid resistor, and thus the auxiliary power supply preferably should be shielded.

ACKNOWLEDGMENT

It is to be acknowledged that an associate of the authors, A. H. Reesor Smith, made the proposal of using a fractional-mu oscillator to generate high voltages.

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(2) O. H. Schade, "Radio-frequency-operated high-voltage supplies for cathode-ray tubes," PROC. I.R.E., vol. 31, pp. 158–163; April, 1943. (Also U. S. Patent No. 2,374,781, May 1, 1945).
(3) U. S. Patent No. 2,300,451, A. H. R. Smith, November 3, 1942, "High-voltage power-supply system."
(4) U. S. Patent No. 2,324,776, R. C. Hergenrother, July 20, 1943, "Vacuum tube."

Contributors to Waves and Electrons Section

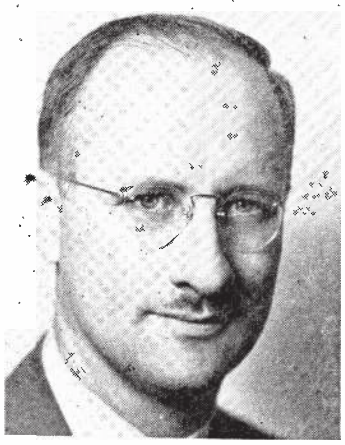
A. Rufus Applegarth, Jr., (A'36) was born at Patchogue, New York, on February 1, 1913. He received the S.B. and S.M. degrees from the Massachusetts Institute of Technology in 1936, after which he became associated with the Philco Radio and Television Corporation as a television development engineer. He joined the RCA Manufacturing Company in 1939 to engage in the design of aviation-radio receivers and airborne radar equipment. Shortly after the outbreak of the war with Japan, he was called to active duty with the Signal Corps, and sent to the aircraft radio laboratory, Wright Field, Dayton, Ohio, where he was assigned to the radar division. He is now vice-president of the Aeronautical Corporation, Camden, New Jersey.

A. RUFUS APPLEGARTH, JR.

❖

Geoffrey Builder (A'32–F'41) was born at Cue, Western Australia, on June 21, 1906. He received the B.Sc. degree from the University of Western Australia in 1928, and the Ph.D. degree from London University in 1933. From 1928 to 1930 he was an observer at the Walheroo, Western Australia, Magnetic Observatory of the Carnegie Institution of Washington. During 1931 and 1932 he was engaged in research work in radio physics at the University of London, and during 1933 and 1934 was a research physicist of the Australian Radio Research Board. From 1934 to 1941 he was in charge of the research and development laboratories

GEOFFREY BUILDER



EDWIN E. SPITZER

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of Amalgamated Wireless (Australasia), Ltd. Since 1941 he has been a consulting engineer.

Dr. Builder is a Fellow of the Institute of Physics, London, a Fellow of the Institution of Radio Engineers (Australia), and an Associate member of the Institution of Engineers (Australia).

❖

George A. Espersen (A'34) was born at Jersey City, New Jersey, on May 17, 1906. He received the B.S. degree in physics in 1931 from New York University. From 1932 to 1939 Mr. Espersen was employed by Hygrade Sylvania Corporation as a development engineer engaged in the development and production of receiving type tubes. He was tube-development engineer for National Union Radio Corporation in 1939 and 1940.

From 1940 to 1942 Mr. Espersen was engaged in research and development of ultra-high-frequency tubes in the research laboratories of the Sperry Gyroscope Company. Since 1942 he has been a development engineer with the North American Philips Company at Dobbs Ferry, New York.

Mr. Espersen is a member of the American Physical Society.

❖

Edwin E. Spitzer (A'28–M'38–SM'43) was born at Fitchburg, Massachusetts, on February 22, 1905. He received the B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology in 1927. Mr. Spitzer was associated with the research laboratory and the vacuum-tube engineering department of the General Electric Company from 1927 to 1933. From 1933 to date he has been head of the power-tube division of the engineering department, RCA-Victor Division of the Radio Corporation of America, Harrison, New Jersey, and since 1943 located at Lancaster, Pennsylvania.

❖

GEORGE A. ESPERSEN

Gordon M. Lee (A'45) was born on January 3, 1917, at Minneapolis, Minnesota. He received the B.E.E. degree from the University of Minnesota in 1938. For the following year he was employed as a research and teaching assistant in electrical engineering at the University of Missouri and received the M.S. degree in electrical engineering from that school in 1939. From 1939 to 1945 he was associated with the Laboratory for Insulation Research at the Massachusetts Institute of Technology, receiving the

GORDON M. LEE

D.Sc. degree in electrical engineering from M.I.T. in 1944.

In 1945 he became one of the technical directors of the newly organized Central Research Laboratories, Inc., of Red Wing, Minnesota, an organization devoted to consultation, research, development, and limited production in the fields of chemistry, physics, and electrical engineering.

Dr. Lee is a member of the American Institute of Electrical Engineers, the American Physical Society, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

❖

Robert L. Freeman (S'32–A'33–SM'45) was born on February 1, 1909, at Cleveland, Ohio. He received the A.B. degree in 1931, the E.E. degree in 1933, and the Ph.D. degree in electrical engineering in 1934 from Stanford University. He was engaged in receiver development with the Crosley Radio Corporation from 1934 until 1937. During 1937 he was transmitter engineer for Farnsworth Television, Inc. From September, 1937, to August, 1945, he was employed by Hazeltine Corporation as senior engineer and as consulting engineer. In August, 1945, he was employed by Lewyt Corporation as chief engineer.

ROBERT L. FREEMAN

Dr. Freeman is a member of Sigma Xi and a Fellow of the Radio Club of America.

❖

R. C. Hergenrother (A'37) was born on September 5, 1903, in Chemnitz, Germany. He received the A.B. degree from Cornell University in 1925. During 1925 and 1926 he was employed in vacuum-tube development work at Westinghouse Lamp Company in Bloomfield, New Jersey. He went to the Pennsylvania State College in 1927 as an instructor in physics and there received the M.S. degree in 1928. He received the Ph.D. degree from California Institute of Technology in 1931.

Dr. Hergenrother held a Rockefeller Foundation Research Fellowship in physics at Washington University, St. Louis, Missouri, from 1932 to 1934. From 1934 to 1935 he was employed by the Farnsworth Television Laboratories of Philadelphia, Pennsylvania, on research and development work on television tubes. From 1935 until recently he worked for the Hazeltine Corporation on electron-tube research and development. He has now joined the communications division of the Raytheon Manufacturing Company in Waltham, Massachusetts.

He is a member of the American Physical Society, Sigma Xi, and Sigma Pi Sigma.

R. C. HERGENROTHER

Institute News and Radio Notes

Outstanding Events of 1946 Winter Technical Meeting

Keynoted by the remarkable public response to the first announcement of radar contact with the moon, the theme of the largest and most successful Winter Technical Meeting in the history of The Institute of Radio Engineers might be characterized, in the words of Dr. Frederick B. Llewellyn, president of the Institute, as one of "intense enthusiasm and a sense of the importance of this field of electronics in the daily lives of men now and in the future."

The four-day meeting from January 23–26, 1946, at the Hotel Astor drew a record registered attendance of 7020 radio-and-electronic engineers and scientists, over 2500 more than had been anticipated. Last year, an estimated 3000 members of the professions attended.

Opening the four-day gathering on Wednesday evening, January 23, was a joint meeting between the Institute of Radio Engineers and the American Institute of Electrical Engineers at the Engineering Societies Auditorium, 33 West 39th Street, New York City, at which Major General Leslie R. Groves, director of the Manhattan District, code name for the atomic-bomb project, was the principal speaker before an overflow crowd. Commenting on many of the background aspects of the gigantic atomic-bomb project, General Groves noted "The United States Army and Navy would have fought the Spanish-American War with radar in all its present uses, if radar progress had advanced as speedily from its beginnings as the atomic-bomb project." The

SOME OF THE SECTIONS' REPRESENTATIVES WHO ATTENDED THE 1946 WINTER TECHNICAL MEETING

First Row (left to right): C. A. Norris, Chairman, Meetings and Papers Committee, Toronto; Alexander Bow, Secretary-Treasurer, Toronto; H. E. Kranz, Chairman, Detroit; W. O. Swinyard, Board of Directors, I.R.E.; W. L. Everitt, Retiring President, I.R.E.; Samuel Gubin, Vice-Chairman, Philadelphia; R. A. Heising, Chairman, Sections Committee; and M. C. Jensen, Representative, Twin Cities.

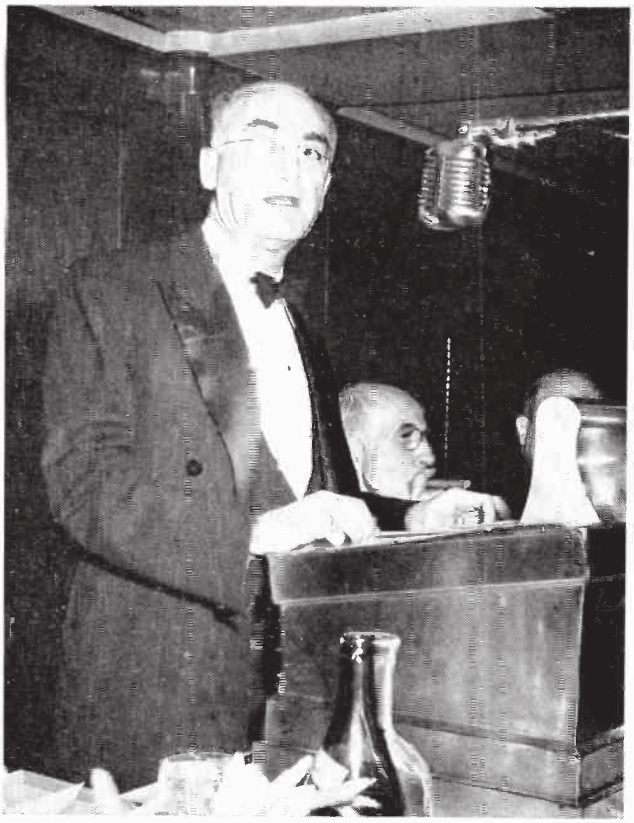
Second Row (left to right): E. B. Swan, Vice-Chairman, Canadian I.R.E. Council, Toronto; G. T. Royden, Sections Committee; F. A. Polkinghorn, Sections Committee; Richard White, Chairman, Kansas City; R. S. Ould, Representative, Washington; C. W. Tirrell, Secretary, San Diego; R. F. Field, Executive Committee, Boston; G. H. Browning, Vice-Chairman, Boston; A. E. Newlon, Secretary, Rochester; and E. M. Dupree, Representing Houston.

Third Row (left to right): N. L. Kiser, Chairman, Emporium; H. E. Smithgall, Chairman, Williamsport; L. A. W. East, Chairman, Montreal; R. R. Desaulniers, Secretary, Montreal; B. E. Shackelford, Sections Committee, New York; E. S. Skelsey, Vice-Chairman, Montreal; R. R. Batcher, Representative, New York; Roy M. Flynn, Chairman, Dallas-Fort Worth; Durward J. Tucker, Representative, Dallas-Fort Worth; W. H. Crew, Assistant Secretary, I.R.E., and H. E. Hartig, Chairman, Twin Cities.

Fourth Row (left to right): F. L. Burroughs, Secretary, Williamsport; F. H. R. Pounsett, Chairman, Toronto; Burwell Graham, Chairman, London; G. B. Hoadley, Chairman, New York; N. J. Zehr, Secretary, St. Louis; R. B. Jacques, Technical Secretary, I.R.E.; B. B. Miller, Chairman, St. Louis; S. L. Bailey, Sections Committee; R. A. Holbrook, Chairman, Atlanta; and J. E. Breeze, Representative, Ottawa.

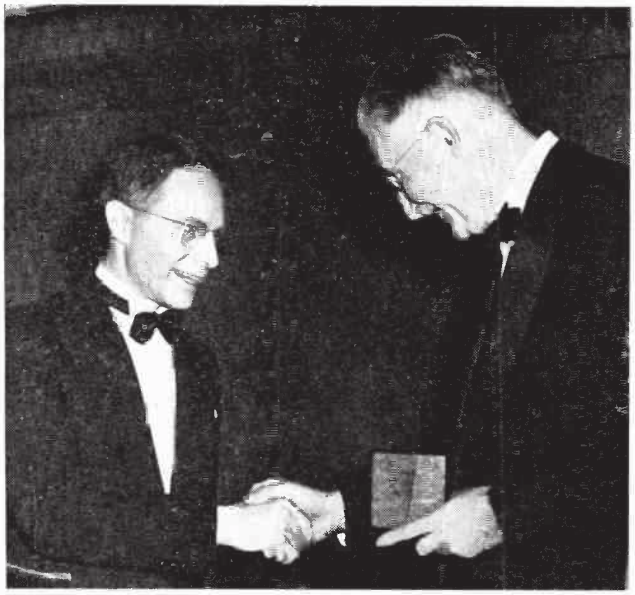
Fifth Row (left to right): Alois W. Graf, Vice-Chairman, Chicago; R. H. Herrick, Executive Committee, Chicago; F. S. Howes, Chairman, Canadian I.R.E. Council, Montreal; H. D. Reid, Chairman, Cincinnati; W. L. Webb, Board of Directors, I.R.E.; T. A. Hunter, Chairman, Cedar Rapids; R. S. Conrad, Secretary, Cedar Rapids; R. N. Harmon, Chairman, Baltimore; V. A. Bernier, Secretary, Indianapolis; and F. W. Albertson, Chairman, Washington.

1946 WIN TECHNICAL



MR. EDGAR KOBAK, President of the Mutual Broadcasting System, acts as Toastmaster at Banquet. Dr. Jewett in background.

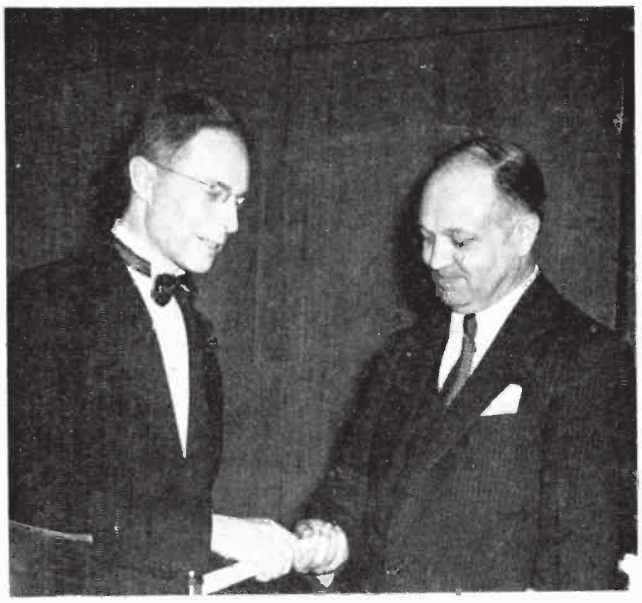
DR. LLEWELLYN presents Morris Liebmann Memorial Prize for 1945 to Dr. Peter C. Goldmark.



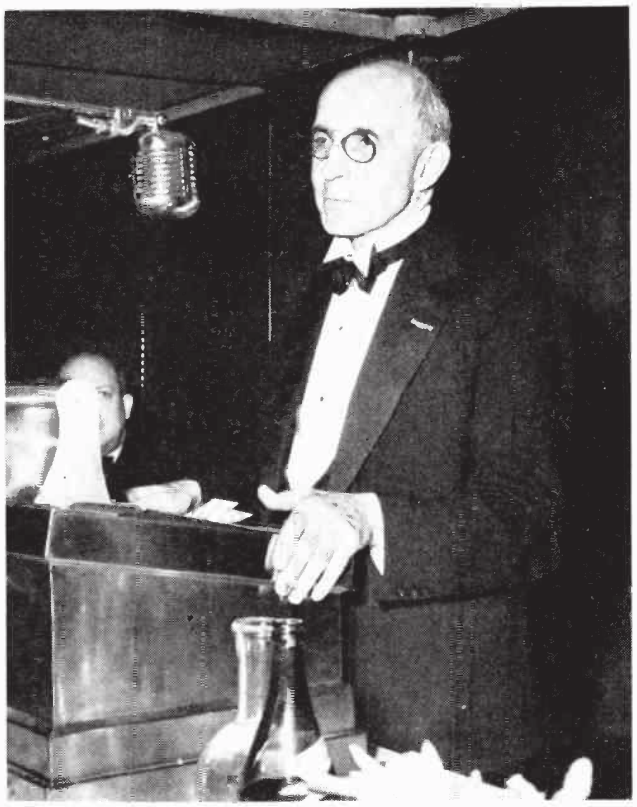
DR. RALPH VINTON HARTLEY receives Medal of Honor for 1946 from Dr. Frederick B. Llewellyn.

MR. RAYMOND A. HEISING Presides over Annual Meeting of Sections' Representatives.

TER I.R.E. MEETING



DR. LLEWELLYN presents Certificate of Fellowship to Dr. Julius A. Stratton who made Speech of Acceptance for all recipients of Fellow Award.



DR. FRANK B. JEWETT, President of the National Academy of Sciences, is Guest Speaker at Banquet.

MR. LEWIS M. CLEMENT, Vice-President in Charge of Research and Engineering, The Crosley Corporation, is Master of Ceremonies at President's Luncheon. Dr. Everitt in background.

DR. WILLIAM L. EVERITT, Retiring President of the I.R.E., Presents Gavel to Dr. Frederick B. Llewellyn, President for 1946, at Annual Meeting.

title of the General's talk was "Some Electrical, Engineering, and General Aspects of the Atomic-Bomb Project."

Presenting a panoramic view of the new world of electronics, a major assembly of radio engineering equipment was shown. One hundred and seventy exhibits of new devices by 135 companies included everything from latest developments in radio receivers to the latest frequency-modulation and television transmitters, from a preproduction model of a camera for the photographic recording of patterns which may appear on a cathode-ray-oscilloscope screen to "packaged antennas," easy to erect 30-foot antenna towers and 150-foot masts.

Radars and radar devices for peacetime use, amplitude- and frequency-modulation radio, television, sound recording, communications, photography, vacuum tubes, magnetic recording, remote-control devices, testing devices, time- and heat-control devices, rectifiers and converters, electronic navigation and direction-finding instruments, and X-ray equipment were a few of the many categories of electronic equipment featured in the exhibit.

Under *radar* were a number of superior designs of signal generators, wave guides, and other components of radars displayed for the first time together with examples of some of the newest radars for peacetime use.

In the *radio field*, one of the newer developments was a new supersensitive loop antenna for receivers. Occupying a section of an entire stage on the main exhibit floor was a radiotelegraph printer system in actual operation and a transmitting and receiving facsimile circuit at work. One feature of particular interest to broadcast engineers was a device shown in actual operation known as a "frequency watchman" which insured synchronized frequency control in frequency-modulation transmitters.

In *television*, a new television pickup and transmission system containing an extremely compact television camera weighing 40 pounds was included among the latest developments.

In *sound recording*, new phonograph pickups, recording turntables, transcription playback units for radio and other professional uses highlighted improved models of home and studio recording. Also on exhibit was a highly developed model of a new magnetic recorder.

In *communications*, mobile radiotelephone equipment of the type suggested for installation in vehicles operating within urban areas was among the new equipment shown.

One of the features in *vacuum tubes* was a 2,000,000-volt X-ray tube in an insulating column consisting of 180 metal-to-glass seals which has a precision control of the electron beam making possible a focal spot as small as one hundredth of an inch.

Other displays of unusual interest were a remote-control system which remotely tunes radio equipment in aircraft; extremely high vacuum pumps; pulse timers for automatic control equipment; a new type of voltage stabilizer for photographic purposes; dual remote-control automatic direction finders, and a new type current converter for automobile radios.

The third major feature of the Meeting was the Annual Banquet held Thursday evening, January 24, at which Dr. Frank B. Jewett, president of the National Academy of Sciences, was the principal speaker. Dr. Jewett declared on his talk before the 2000 members and their guests present, that our Nation's fundamental scientific resources were dangerously depleted. "We drew heavily on our scientific resources in this war," Dr. Jewett said, "and must get back again as soon as possible to serious researches in fundamental sciences. We must remember that our success in applied science adds very little to the source of all science which is fundamental research, and indeed the amazing success of such programs as the atomic-bomb project and the radar program draw heavily upon fundamental science and mobilize the brains and resources of our best men on a limited number of projects to the detriment of other equally vital fields."

At the Banquet also, two special awards and fifteen Fellowships were presented. The Institute Medal of Honor was awarded to Ralph Vinton Lyon Hartley, engineer of Bell Telephone Laboratories "for his early work on oscillating circuits employing triode tubes and likewise for his early recognition and clear exposition of the fundamental relationship between the total amount of information which may be transmitted over a transmission system of limited bandwidth and the time required." Dr. Peter C. Goldmark, engineer of the Columbia Broadcasting System, was the recipient of the Morris Liebmann Memorial Prize, "for his contributions to the development of television systems, particularly in the field of color." Fellowships were awarded to the following engineers: Gregory Breit, Henri G. Busignies, Howard A. Chinn, Thomas Lydwell Eckersley, Walter C. Evans, Clarence W. Hansell, Harold Lester Kirke, Elmer D. McArthur, Harold S. Osborne, Ronald J. Rockwell, Arthur L. Samuel, Joseph Slepian, Julius A. Stratton, William O. Swinyard, and Merle A. Tuve.

The fourth major feature of the Meeting was the President's Luncheon, honoring the incoming president, Dr. Frederick B. Llewellyn. The principal speaker was Paul Porter, then chairman of the Federal Communications Commission, who told 1000 luncheon guests that the radio industry has three main and immediate assignments: the construction of an entirely new system of aural broadcasting—frequency modulation—complete with thousands of transmitters, millions of receivers, and a nationwide network; the construction of a nationwide system of television, and the construction of scores of radio systems for a wide variety of uses to promote safety and efficiency.

Mr. Porter stressed the need for continued support

of the Federal Government in the realm of pure scientific research. "No one knows better than the radio engineer the frontiers that still remain to be conquered in the field of communications," he asserted. "These are tasks of such magnitude and of such general benefit to the entire field that no one company can or should be expected to undertake them. They are proper concerns of the Federal Government. It is plain that we shall have no alternative in this matter. Either research into pure science is to be aided by the Federal Government or much of it will simply be left undone."

At the cocktail party, which was held in the Grand Ballroom of the Hotel Astor on January 25, over 1700 members of the Institute and friends attended.

The women's activities were participated in by 171 guests who registered. On Thursday, January 24, 89 women were taken for a trip through the Cathedral of St. John the Divine; luncheon was served at Stoddard's Restaurant; and a tour of Riverside Church was provided. On Friday, January 25, 107 women were the guests of the I.R.E. and were conducted to the Museum of Costume Art, Sloane's House of Years, and the Public Library. Luncheon was served at the Town Hall Club where Mr. E. Stanley Turnbull had his pictures on display and painted a portrait of one of the women guests. Later in the afternoon, the group was taken to Radio City for a television tour.

Finally, the major features of every annual meeting—the reading of scientific papers and the sessions and symposia on the latest electronic developments—took on particular significance this year with a record number of 87 papers in 16 categories of subjects, many hitherto restricted by military security. The subjects of the sessions were: Military Applications of Electronics; Frequency Modulation and Standard Broadcasting; New Circuit Developments; Television; Radio Navigation Aids; Vacuum Tubes; Microwave Vacuum Tubes; Antennas; Radar; Microwave Techniques; Crystal Rectifiers; Industrial Electronics; Communications Systems and Relay Links; Radio Propagation; Broadcast Receivers; and Quartz Crystals.

One of the important papers of these sessions was recorded and played before a special meeting of the British Institution of Electrical Engineers in London, while its author, J. A. Pierce of the Radiation Laboratory of the Massachusetts Institute of Technology was delivering the paper in person at the meeting in New York. The subject was loran, a radar system that holds great promise for peacetime application and the title of the paper was "An Introduction to Hyperbolic Navigation." In his talk, Mr. Pierce outlined the possibilities of ships and planes automatically navigating straight to their destinations half a world away in any kind of weather; pilotless aircraft being controlled and guided from a great distance with unheard-of accuracy and large areas of the earth's surface being surveyed and charted in far less time than is required by conventional methods through development of loran.

Among other interesting facts which emerged from the many outstanding papers presented was the fact that more than 2,500,000 tons of Japanese shipping had been sunk during the war through the use of sonar, a supersonic device mounted on the hulls of submarines and surface vessels of many types. This information came from a paper entitled: "Navy Radio and Electronics in World War II," by Commodore J. B. Dow of the Navy's Bureau of Ships. Successful invasion of the ultra-high frequencies by high-power, high-definition, full-color television was described in a paper by Dr. Peter C. Goldmark of Columbia Broadcasting System, entitled "Television in the Ultra-High Frequencies." In a paper on "Metal-Lens Antennas", by W. E. Kock of the Bell Telephone Laboratories, new lens antennas made of thin metal strips which resemble venetian blinds were discussed and demonstrated and their use in the future in radio-relay links pointed out.

A Naval radar-directed bomb known under the code name of the "Bat" originated and sponsored by Captain Dundas P. Tucker of the Naval Bureau of Ordinance was described in a paper entitled "Radar Aspects of Naval Fire Control" before the session on Radar. The Bat was a flying bomb with a small fire-control type of fully automatic radar placed in its nose which guided the bomb to its assigned target. "Here," Captain Tucker pointed out, "was a robot 'suicide pilot' far better than his Japanese counterpart."

In a paper entitled "From Wiring to Plumbing" E. M. Purcell of the Radiation Laboratory of Massachusetts Institute of Technology told why engineers must be familiar with plumbers' techniques, in order to put together wave guides, which are metal pipes used for the transmission of ultra-high-frequency radio waves.

PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS

From month to month, it is hoped more clearly to differentiate the nature of the contents of the PROCEEDINGS OF THE I.R.E. Section from those of WAVES AND ELECTRONS Section, and to develop in the latter Section an increasingly distinctive character. In the meantime, the Board of Editors will be grateful for any comments, criticisms, or suggestions relative to WAVES AND ELECTRONS Section. Only through the accumulation of viewpoints, and careful consideration of such proposals, can normal progress and improvement be anticipated.

Board of Directors

January 9 Meeting: At the final meeting of the 1945 Board of Directors, which was held on January 9, 1946, the following were present: F. B. Llewellyn, president-elect (guest); G. W. Bailey, executive secretary; S. L. Bailey, W. R. G. Baker, Alfred N. Goldsmith, editor; V. M. Graham, R. F. Guy, Keith Henney, B. E. Shackelford, D. B. Sinclair, and W. C. White.

Approval of Executive Committee Actions: The actions of the Executive Committee taken at its December 5, 1945, meeting were unanimously approved.

January 9 Meeting: At the annual meeting of the Board of Directors for 1946, the following were present: F. B. Llewellyn, president; G. W. Bailey, executive secretary; S. L. Bailey, W. R. G. Baker, Alfred N. Goldsmith, editor; V. M. Graham, R. F. Guy, Keith Henney, L. C. F. Horle, B. E. Shackelford, D. B. Sinclair, and W. C. White.

1946 Budget: After a careful consideration of the various items of the budget, the Board adopted the recommendation of the Executive Committee that the Budget, as presented, be approved.

Appointments and Committees: The following appointments were unanimously approved:

SECRETARY

Haraden Pratt

TREASURER

William C. White

EDITOR

Alfred N. Goldsmith

APPOINTED DIRECTORS—1946

R. A. Hackbusch	W. O. Swinyard
F. R. Lack	W. L. Webb
G. T. Royden	E. M. Webster

TECHNICAL SECRETARY

Robert Blair Jacques

GENERAL COUNSEL

Harold R. Zeamans

Committees

The following members were appointed.

AWARDS

E. W. Engstrom, *Chairman*

Ralph Bown	W. B. Lodge
D. E. Harnett	G. T. Royden
Keith Henney	W. C. White

CONSTITUTION AND LAWS

R. F. Guy, *Chairman*

G. W. Bailey	L. C. F. Horle
I. S. Coggeshall	B. E. Shackelford
R. A. Heising	F. E. Terman

H. R. Zeamans

EXECUTIVE

S. L. Bailey R. F. Guy

Keith Henney

NOMINATIONS

S. L. Bailey, *Chairman*

E. J. Content	D. D. Israel
Beverly Dudley	R. C. Poulter
W. L. Everitt	P. F. Siling

W. C. White

TELLERS

Trevor Clark, *Chairman*

H. A. Chinn	W. G. Moran
H. M. Lewis	J. E. Shepherd

WAR MEDALS

(Subcommittee of Awards Committee)

Ralph Bown, *Chairman*

F. S. Barton	G. F. Metcalf
J. B. Dow	J. A. Stratton
L. A. DuBridge	A. H. Taylor
Melville Eastham	F. E. Terman
E. W. Engstrom	M. A. Tuve
W. L. Everitt	A. F. Van Dyck
J. W. McRae	W. C. White

RTPB REPRESENTATIVE

D. B. Sinclair

Alfred N. Goldsmith (alternate)

Building-Fund: B. E. Shackelford, chairman of the I.R.E. Building-Fund Committee, reported that the amount subscribed to date is $625,545.77.

Code of Ethics: The recommendations that the functions of the Code of Ethics Committee be combined with the Committee on Professional Recognition and that the membership of the first-named committee be discharged with thanks and that the records of the first-named committee be forwarded to the chairman of the Committee on Professional Recognition was unanimously approved.

Office-Quarters: The Executive Secretary read a report of the Office-Quarters Committee, and a letter from General Counsel Zeamans, reporting the acquisition of the new I.R.E. Building at Fifth Avenue and 79th Street, New York, N. Y.

Constitution and Bylaws

Article II, Sec. 9: It was approved that the following wording be adopted for Article II, Sec. 9, and the amendment as modified be submitted to the membership:

"Sec. 9—Graduation from a radio or electrical course of a school of recognized standing shall be accepted as equivalent to two years experience in radio or allied fields. Full-time graduate work, or part-time graduate work with teaching in radio or allied courses in a school of recognized standing, shall be accepted as equivalent to professional experience, for a period not exceeding one year."

Article V: Unanimous approval was given to the proposed Constitutional Amendment to change the title of Article V from "Officers" to "Officers and Directors," to be submitted to the membership.

Article V, Sec. 5: It was unanimously approved that the following wording be adopted for Article V, Sec. 5, and the amendment as modified be submitted to the membership:

"Sec. 5—No Officer nor Director shall receive, directly or indirectly, any salary, traveling expense, compensation, or emolument from the Institute, unless authorized by the Board of Directors, or by the Bylaws."

Article VI, Sec. 7: The following wording was approved for adoption for Article VI, Sec. 7, and the amendment as modified submitted to the membership:

"Sec. 7—All committees shall be appointed by the Board of Directors or in such manner as the Board may designate."

Bylaw Section 22: The recommendation of the Constitution and Laws Committee that Bylaw Section 22 be eliminated was unanimously approved.

Bylaw Section 46: Unanimous approval was given to the following wording to be adopted for Bylaw Section 46:

"Sec. 46—The standing committees, each of which shall normally consist of five or more persons, shall include the following:

Admissions	Annual Review
Appointments	Antennas
Awards	Circuits
Board of Editors	Electroacoustics
Constitution and Laws	Electron Tubes
Education	Facsimile
Executive Committee of the Board of Directors	Frequency Modulation
	Handbook
	Industrial Electronics
Investments	Medical Electronics
Membership	Radio Receivers
Nominations	Radio Transmitters
Papers Procurement	Radio Wave Propagation and Utilization
Papers Review	
Public Relations	Railroad and Vehicular Communication
Sections	
Tellers	Research
	Standards
	Symbols
	Television

"On matters which are reasonably described by the committee names, these committees shall be advisory to the Board of Directors or the Executive Committee, whichever appoints them and directs their activities.

"The terms of appointments of the Admissions, Awards, Board of Editors, Constitution and Laws, Education, Investments, Membership, Nominations, Papers Procurement, Papers Review, Public Relations, Sections, and Tellers Committees shall start with the first day of the month following appointment and continue until the date the succeeding terms of appointments take effect. The Board may specifically advance or delay the terminating date of any committee and the starting date of a succeeding committee. Appointments shall be made to the following committees: Annual Review, Antennas, Circuits, Electroacoustics, Electron Tubes, Facsimile, Frequency Modulation, Handbook, Industrial Electronics, Medical Electronics, Radio Receivers, Radio Transmitters, Radio Wave Propagation and Utilization, Railroad and Vehicular Communication, Research, Standards, Symbols, and Television, each year between January first and May first and the terms of appointment shall be from May first of the year when the appointments are made until April thirtieth of the following year. Additional appointments may be made to fill vacancies or to care for special cases as the need arises, with the term of the appointment expiring April thirtieth."

Bylaw Section 49: Approval was given to the following wording to be adopted for Bylaw Section 49:

"Sec. 49—The Appointments Committee shall be appointed by the Board of Directors at its regular November meeting,

Its membership shall be chosen from the continuing and newly elected members of the Board of Directors. At least fourteen days before the next annual meeting of the Board of Directors, the Appointments Committee shall mail to the members of the new Board of Directors, a list of candidates for the Offices of Secretary, Treasurer, Editor, and Appointed Directors, and Chairmen and members of the Awards, Constitution and Laws, Executive, Investments, Nominations, and Tellers Committees."

Bylaw Section 53: It was unanimously approved that Bylaw Section 53 be changed to read as follows:

"Sec. 53—The President is authorized to appoint teachers of science or engineering who are Institute members as Institute Representatives. Each such Institute Representative is charged with promoting the welfare of the Institute at his school, particularly in matters relating to Student membership."

Bylaw Section 54—It was unanimously approved that the following wording be adopted for Bylaw Section 54:

"Sec. 54—The Board of Directors may appoint or direct the appointment of representatives of the Institute on joint committees, boards, and other local, national, and international bodies."

Awards: It was approved that all awards in the future shall be made by the Board, upon the recommendation of the Awards Committee, and the Board shall reserve the right to make such changes and additions as it deems desirable.

Morris Liebmann Memorial Fund: On recommendation of Mr. Heising, Treasurer, and the Board, Executive Secretary Bailey, wrote to Mr. Emil J. Simon, donor of the Morris Liebmann Memorial Fund, requesting his approval of a set of modified terms with reference to the Award as follows:

"First—That the award be made to that member of the Institute, who, in the opinion of the Board or its appointed committee, shall have made the most important contribution to the radio art during the preceding calendar year, but that the Board may deviate from these terms when, in its opinion, there are suitable and sufficient reasons, and when it believes the spirit of the award will still be properly satisfied.

"Second—That the fund may be invested in such securities as the Investments Committee of the Institute of Radio Engineers elects, including both stocks and bonds.

"Third—That the Committee on the award may be either a special Committee or the regular Committee of the Institute on other awards.

"Fourth—That the Board in its discretion may estimate the proper amount of an annual award giving effect to possible fluctuations in income so as to have the amount of the award substantially the same for each year in the future, and pay such sum annually, accumulation of any excess to be finally paid out by change in annual award.

"Fifth—The time of the award may be varied by the Board in charge provided it is once for each year."

Mr. Simon replied that he was agreeable to modifying the terms of the Award as outlined above.

Sections

Columbus: Approval was given to the recommendation of the Executive Committee that the petition of Columbus members for the formation of a Columbus Section be approved.

Executive Committee

January 9 Meeting: The Executive Committee Meeting, held on January 9, 1946, was attended by F. B. Llewellyn, president-elect (guest); G. W. Bailey, executive secretary; S. L. Bailey, W. L. Barrow, W. H. Crew, assistant secretary; Alfred N. Goldsmith, editor; and R. A. Heising, treasurer.

Membership: Approval was given to the 360 applications for membership in the Institute as listed on page 42A in the February, 1946, issue of the PROCEEDINGS OF THE I.R.E. and WAVES AND ELECTRONS. These applications are as follows:

For Transfer to Senior Member Grade	14
For Admission to Senior Member Grade	12
For Transfer to Member Grade	71
For Admission to Member Grade	81
For Admission to Associate Grade	131
For Admission to Student Grade	51
Total	360

Fifth Avenue at 79th Street: Mr. Heising, chairman of the Office-Quarters Committee, reported that the final purchase of the property at Fifth Avenue at 79th Street, New York, N. Y. had been consummated on December 28, 1945, that the architect is making up drawings, copies of which were not available as yet, and that the plans would have to be presented to the Department of Housing.

Office-Quarters Committee: The Office-Quarters Committee for the year 1946 will consist of R. A. Heising, chairman; F. B. Llewellyn, Haraden Pratt, Alfred N. Goldsmith, and George W. Bailey.

Papers Procurement Committee: The Editorial Department, on behalf of the Papers Procurement Committee, some time ago sent out a letter from Dorman D. Israel and E. T. Dickey to all Group and Subgroup Chairmen of the Papers Procurement Committee furnishing information which was secured from the postcard survey on promised papers. Thus, it was made possible for each Group chairman to secure papers systematically from the survey made on the postcards.

Appointments

The following appointments were unanimously approved:

Mr. R. F. Guy to serve as Mr. A in charge of technical committees.

Mr. S. L. Bailey to serve as Mr. B in charge of Sections' activities.

Mr. Keith Henney to serve as Mr. C in charge of certain standing committees such as Admissions, Membership, and Public Relations.

FACSIMILE COMMITTEE

Pierre Mertz

Technical Secretary: Executive Secretary Bailey announced that, in accordance with authorization by the Executive Committee and the Board of Directors, Robert Blair Jacques had been engaged as the new technical secretary to take office on February 1, 1946.

American Standards Association: The Executive Committee authorized the payment of $500 membership fees to the ASA Standards Council, subject to the approval of the 1946 Budget.

I.R.E. People

C. P. SWEENEY

C. P. Sweeney has returned to the National Broadcasting Company's engineering department as a member of the technical staff of the television transmitter in the Empire State Building in New York after service with the United States Navy as a Lieutenant Commander.

Mr. Sweeney joined NBC in 1939 as development laboratory engineer and was called to the Navy as a Lieutenant (s.g.) in 1941. He served as radio officer and radio materiel officer at Casablanca before returning to the United States to head the major shore section of the electronic field service group at the Naval Reserve Laboratory, Washington, D. C. In 1944, Mr. Sweeney was transferred to the Radio Engineering Planning Board of the Commander-in-Chief of the Pacific Fleet, serving as executive officer with the group which designed and supervised installation of Radio Guam. He completed his naval service in 1945 as an electronic ship superintendent at Mare Island, California.

J. B. SCHAEFER

J. B. Schaefer (A'37–SM'45) has been appointed plant manager of the New York Transformer Company. He will direct engineering and manufacturing activities at the Alpha, New Jersey, plant and have charge of reconversion.

Mr. Schaefer formerly was associated with the Sperry Gyroscope Company as engineering manager. He was responsible for several of Sperry's most important war projects and acted as transformer consultant for the company.

VERNON B. BAGNALL

VERNON B. BAGNALL

Vernon B. Bagnall (A'30–M'40–SM'43) has returned to the long-lines department of the American Telephone and Telegraph Company as division plant superintendent for the territories of Maryland, Virginia, West Virginia, and District of Columbia, after four years in the United States Signal Corps.

Colonel Bagnall received his B.S. degree in electrical engineering at the University of Wisconsin in 1927 and the M.S. from New York University in 1933. He joined the long-lines department in 1927 as technical employee in Chicago, Illinois, after which he was transferred to New York as radio engineer and circuit-layout engineer.

In 1942, he entered the Signal Corps as Captain and was assigned Officer in Charge, Radio Branch, Plant Division. In 1943, Colonel Bagnall was appointed Chief, Communications Engineering Branch, Army Communications Service, Office of the Chief Signal Officer, with responsibility for the over-all engineering of the world-wide radio and wire network established by ACS. He participated in making practicable the use of teletypewriters on radio circuits which formed the basis of the Army's telegraph communications system. He supervised the engineering of the communications arrangements for the Anglo-American and Big-Three conferences at Quebec, Cairo-Teheran, Malta-Yalta, and Potsdam, and also supervised the installation and operation of facilities at the Pottsdam and first Quebec conferences.

Colonel Bagnall made two other trips to the European theater, the first in connection with planning communications for the invasion of Europe, and the second in connection with rehabilitation and establishment of communications in France following the Allied Armies' push through that country. He also participated in an engineering survey of communications on the Air Transport Command's South Atlantic air-ferry route to establish radioteletype facilities which would expedite the movement of aircraft. Colonel Bagnall was awarded the Bronze Star and the Legion of Merit for his services.

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BEVERLY F. FREDENDALL

RAY H. DE PASQUALE

RAY H. DE PASQUALE

Ray H. de Pasquale (A'43) has been appointed vice-president and general manager of the recently organized Press Wireless Manufacturing Corporation of New York. Mr. Pasquale formerly was director of manufacturing for Press Wireless, Inc.

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BEVERLY F. FREDENDALL

Beverly F. Fredendall (A'29) is now associated with Frederick Hart and Company, Inc., specializing in the design and manufacture of recording equipment. Mr. Fredendall previously was with the National Broadcasting Company for sixteen years in operation and design of audio and video broadcast systems including the field of recording. Until recently, he was located at the NBC midwest headquarters in Chicago.

❖

WALTER S. LEMMON

Walter S. Lemmon (SM'45) has been named a vice-president of Globe Wireless, Ltd. Globe has acquired from International Business Machines Corporation its interest in the radio-type developments of Walter S. Lemmon and Associates.

ADOLPH B. CHAMBERLAIN

ADOLPH B. CHAMBERLAIN

Adolph B. Chamberlain (A'27–M'30–F'42) was commissioned a Captain (SE3)T in the United States Naval Reserve in July, 1945. Captain Chamberlain has been active in radio work since 1920, and has served on general and technical committees of the I.R.E. He is a past chairman of the Rochester and Buffalo Sections. On December 24, 1945, he resumed his position as chief engineer of the Columbia Broadcasting System.

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HOWARD S. FRAZIER

Howard S. Frazier (A'27–M'43–SM'43) has announced the formation of a radio management consulting practice, with offices in Washington, D. C.

Mr. Frazier entered the amateur radio field in 1919, and in 1922, engaged in the manufacture and sale of radio parts and the custom building of broadcast receivers. From 1925 to 1932, he was located in Philadelphia, Pennsylvania, as control operator of WCAU, chief engineer of WABQ, partner and chief engineer of WPSW, and chief engineer of WPEN and WRAX. He was also chief engineer of WOAX, Trenton, New Jersey, and WOAB, New York City. In 1933, he became chief engineer of the General Broadcasting System and two years later was consulting

HOWARD S. FRAZIER

ROYAL V. HOWARD

❖

broadcast engineer practicing before the Federal Communications Commission. In 1937, Mr. Frazier became president and general manager of WSNJ, Bridgeton, New Jersey. As sales engineer for the Radio Corporation of America in 1942, he was in charge of United States Navy contracts, and later that year, he was named director of engineering of the National Association of Broadcasters.

Mr. Frazier is vice-chairman of the Radio Technical Planning Board and chairman of its Panel 4 on Standard Broadcasting. He is chairman of the Radio Manufacturers Association's Subcommittee on Satellite Amplitude-Modulated Broadcast Transmitters, acting director of engineering and secretary of the Executive Engineering Committee of NAB, alternate representative of RTPB on the Radio Propagation Executive Council, and a member of H. V. Kaltenborn's "Twenty-Year Club." He has recently been elected vice-president of Freeland and Olschner Products, Inc., of New Orleans, Louisiana, in charge of sales and finance. Mr. Frazier served as a member of the I.R.E. Winter Technical Meeting Committee and is a member of the I.R.E. Papers Committee.

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UNIVERSAL RESEARCH LABORATORIES

Royal V. Howard (M'41–SM'43) has been named director of the Universal Research Laboratories in San Francisco, California, established for the performance of radio engineering consultant work. His associates are F. Richard Brace (A'36–M'44), Allan A. Kees (M'44), Alfred E. Towne (A'30), and Melvin P. Klein (A'43).

Mr. Howard, one of the early workers in short-wave and aircraft communications, has been engaged in the radio field for the past twenty years. During the last twelve years of this period, he was director of engineering for KSFO, KWID, KWIX, and KPAS. He returned from Europe early in 1945 where he headed a special scientific staff and directed the Operational Analyst Staff at United States Army Headquarters for one year. Mr. Howard is vice-president of engineering of both the Associated Broadcasters, Inc., and the Universal Broadcasting Company, and is chairman of the San Francisco Section of the I.R.E. for 1946.

A graduate of the United States Naval Academy, Mr. Brace studied radio at the University of California and the Radio Institute of California. After a period of active duty with the Navy, he became chief of engineering plans of the Associated Broadcasters, Inc., and is in charge of directional-antenna design and engineering plans at the Laboratories.

Mr. Kees, engineering expert and studio construction specialist for the Laboratories, attended Shanghai American School and St. John's University, Shanghai, China. He served with the United States Navy for five years specializing in Naval radio and underwater sound. Mr. Kees performed radio research and was chief engineer of a prominent broadcast station for seven years before joining KSFO where he is chief of audio facilities.

Mr. Towne received the B.S. degreee in electrical engineering from the California Institute of Technology. Before becoming chief of transmitter facilities for KSFO, KWID, and KWIX in 1937, he served as test engineer for the Radio Corporation of America and General Electric Company, and as radio test and design engineer in San Francisco. Besides design, Mr. Towne handles transmitter and antenna field engineering for the Laboratories.

F. RICHARD BRACE

Mr. Klein received his electrical engineering training at Denver University, University of Colorado, and the University of California. He was associated with the Aircraft Radio Laboratory in Denver, and was consulting engineer for the Air Transport Command in Alaska. In San Francisco, he was affiliated with the Office of War Information, after which he became engaged in broadcast consultant work in Washington, D. C. Mr. Klein served with the Office of Scientific Research and Development as scientific consultant in radar in the southwest Pacific area.

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CARMAN RANDOLPH RUNYAN, JR.

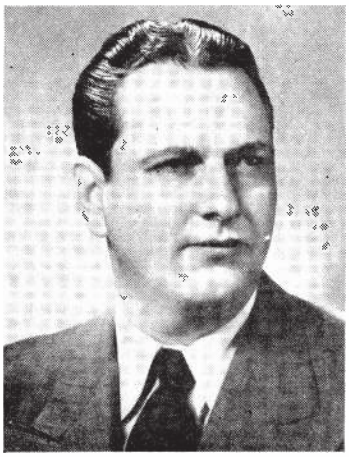
Carman Randolph Runyan, Jr., (A'18) was recently awarded the Armstrong Medal of The Radio Club of America for outstanding contributions to the radio art. The citation stresses his development of the multispark synchronous-gap transmitter, the crystal-controlled frequency-modulated telegraph system, the single-signal radiotelegraph receiver, and the 100-megacycle frequency-modulated broadcast transmitter.

❖

ALLAN A. KEES

MELVIN P. KLEIN

ALFRED E. TOWNE



LEONARD F. CRAMER

LEONARD F. CRAMER

Allen B. DuMont (M 30–F'31), president of the Allen B. Du Mont Laboratories, Inc., Passaic, New Jersey, recently announced the appointment of Leonard F. Cramer (A'44) as director of the newly established television-broadcast division. Mr. Cramer has been the vice-president and a director of the Company since 1942.

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NORMAN S. KORNETZ

Norman S. Kornetz (A'39) has recently been appointed project engineer in charge of Westinghouse television-receiver development. He will have charge of all Westinghouse home television-receiver development, with emphasis on receiving units to be used in flight tests of stratovision.

Born in Boston, Massachusetts, Mr. Kornetz was graduated from Massachusetts Institute of Technology in 1935 with a B.S. degree in electrical engineering. He remained at M.I.T. during the next three years serving with the Division of Industrial Co-operation. In 1938, he joined the American Television Corporation of New York City. Later that year, Mr. Kornetz went to Buffalo to become a member of the staff of the Colonial Radio Corporation where he was located until he joined the U. S. Signal Corps in September, 1942. Mr. Kornetz has recently returned to this country from India where, as a captain with the 3105th Signal Service Battalion, he was in charge of all administrative radio communications in the Calcutta area.

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L. W. CHUBB AND EDWIN H. COLPITTS

L. W. Chubb (M'21–F'40) was elected vice-chairman of The Engineering Foundation, and Edwin H. Colpitts (A'14–F'26) was re-elected director at the annual meeting of that organization held on October 18, 1945. Dr. Chubb is director of the Westinghouse Electric Company's research laboratories, and Dr. Colpitts formerly held the position of director of the Bell Telephone Laboratories.

The Engineering Foundation was established in 1913 for "the furtherance of research in science and engineering and for the advancement in any other manner of the profession of engineering and the good of mankind."

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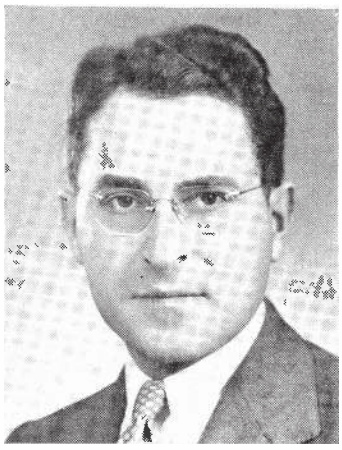
AUSTEN M. CURTIS

AUSTEN M. CURTIS

Austen M. Curtis (M'13–SM'43), member of the transmission research staff of Bell Telephone Laboratories, died in South Orange, New Jersey, on December 22, 1945, Mr. Curtis was born in Brooklyn, New York, in 1890.

Leaving Heffley Institute in 1907, he shipped as wireless operator for the United Wireless Company. Three years later, he became chief operator and installer for the radio systems of a Brazilian shipping company, and in 1912 had charge of radio operations on an exploring expedition for the Brazilian Department of Agriculture. Mr. Curtis joined the Western Electric engineering department in 1913 engaging in telephone instruments study and the radio research that took him to Paris for the transatlantic tests of 1915. It was he who listened at the Eiffel Tower radio receiver when spoken words were first transmitted across the Atlantic.

A member of the Army Signal Corps in World War I, he became a Captain in the Division of Research and Inspection in Paris. Returning to Western Electric's research department after the war, Mr. Curtis developed systems for telegraph communication over submarine cable, with particular emphasis on his work in recording oscillographs. He was responsible for the development of echo suppressors and volume limiters, and engaged in the study of contact phenomena which occupied his attention until his death. During World War II, Mr. Curtis made important contributions to secret scientific projects undertaken by Bell Telephone Laboratories for the United States Government.



NORMAN S. KORNETZ

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G. ROBERT MEZGER

G. Robert Mezger (A'37) has rejoined the Allen B. DuMont Laboratories, Inc., Passaic, New Jersey, as manager of instrument sales after four and one-half years in the United States Navy.

Commander Mezger first joined the DuMont engineering department in 1936 following his graduation from Rensselaer Polytechnic Institute with a degree in electrical engineering. His first Naval assignment in 1941 was with the electronics section of the David Taylor Model Basin, Washington, D. C., where he was concerned with the development of electrical equipment for studies in stress, strain, and vibration problems on ships. In 1944, Commander Mezger attended the Navy's preradar and radar schools, after which he was appointed to the staff of the Electronics Maintenance School at Pearl Harbor.

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LEROY C. ANDERSON

Sergeant Leroy C. Anderson (A'39) lost his life when the ship on which he was being transported. from the Philippine Islands was torpedoed and sunk on October 24, 1944. Sergeant Anderson was born April 2, 1918, and he was graduated from Burlington High School, Burlington, Wisconsin, in 1936, and later from a radio and television school in Chicago. At the time of his induction into the Armed Forces, Sergeant Anderson was employed at the Burlington Mills. In February, 1942, General Douglas MacArthur awarded Sergeant Anderson the Distinguished Service Cross for extraordinary heroism in action, he being the first selectee to be so honored.

PROCEEDINGS of the I.R.E. AND WAVES and ELECTRONS

Published Monthly
by
The Institute of Radio Engineers, Inc.

April, 1946

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Responsibility for the contents of papers published in the PROCEEDINGS OF THE I.R.E. and WAVES AND ELECTRONS rests upon the authors.
Statements made in papers are not binding on the Institute or its members

The future of science and technology are independent in considerable measure upon the major journals in these fields. In their pages are presented the advances in these fields. The stimulating educational effect and the practical results of such publications are of major importance.

It has accordingly seemed appropriate to present guest editorials from the Editors who are leaders of thought in these fields of publication. There accordingly follows a guest editorial by the Editor of the *Review of Scientific Instruments*, a publication of the American Institute of Physics.

The Editor

Journals in Science

G. P. HARNWELL

A most striking feature of our citizen Army and Navy was the level of technical talent and individual competence in dealing with electrical and mechanical devices exhibited by the men who came into all ranks. It was a war of technology to a degree never before known, and the skilled employment of military devices and instruments by men with a flair for their maintenance and operation made their efforts more effective and saved many American lives. Resource and initiative based on an innate aptitude for contrivances of all sorts, shared by designers, manufacturers, and GI users, surmounted obstacles of production and overcame inadequacies in the field by ingenious improvisation.

The same facility with instruments and devices will in turn accelerate reconversion and the resumption of our material and industrial progress when the human and economic problems in which we have not demonstrated comparable dexterity are solved. Not only will the application of perfected machines and techniques improve our standards of health and living, but the stimulus to our thought and ingenuity will accelerate future research and exploration. Our broad educational base has enabled our insatiable scientific curiosity and the urge of individual and corporate competition to create such a body of scientists and technologists in our country as has never before been known.

The technical periodicals, through which advances in basic research and technical application to engineering and industry are disseminated, constitute the circulatory system upon which the great body of scientists depends for stimulus and integration. Our common technical strength exceeds the sum of the separate abilities of each laboratory and enterprise, because of the fertilizing flux of knowledge and information constantly emerging from laboratories and plants that reaches us through journals sponsored by societies and institutes. The obligation of the scientist and engineer to society is not discharged until a record of his technical achievements is published and made a part of that common knowledge from which he has himself drawn in making his contribution.

The vigor of our technical periodicals is a measure of the strength of our scientific growth. The ability to continue to improve upon our present material facilities for peacetime living and to maintain and enhance our standards in competition with all is contingent upon our recognition of the role of technical publication in our society. We owe a great debt to the broad vision of our scientific predecessors who established media for the dissemination of scientific ideas and maintained the standards of excellence for them of which we may be justly proud. It is our obligation as members of the vital scientific subcommunity within our nation to support our journals both as subscribers and contributors and to maintain thereby the enviable technical tradition of which we are the inheritors.

Virgil Miller Graham

Board of Directors—1946

Virgil Miller Graham was born in Rochester, New York, on January 22, 1902. In the early days of radio broadcasting, 1921–1922, he manufactured and sold components such as "single-layer" coils, to replace the currently popular honeycomb coils in tuners, and reactance-coupling units for radio-frequency amplifiers. In 1923 he joined the engineering department of the Stromberg-Carlson Telephone Manufacturing Company and had a part in the design and production of the first broadcast receivers manufactured by that company. He became engineer in charge of the broadcast receiver design, which position he held until 1935. In 1925 Mr. Graham became interested in radio standardization with the radio division of the, then newly formed, National Electrical Manufacturers Association and continued active in this work during the life of that division until around 1928. During this time he did the editorial work on the NEMA Handbooks of Radio Standards that were published. In 1930 he was appointed standards chairman in the RMA Engineering Committee until 1934 when he became assistant director of the RMA Engineering Department, and since 1942 he has been associate director. In the fall of 1935 he joined the Hygrade Sylvania Corporation and became director of the tube-application department in Emporium, Pennsylvania. Until the war he was engaged to a large degree in foreign sales promotion and patent defense work, in addition to the domestic commercial engineering activities of his department. At the start of the defense program, he organized the application engineering department at Emporium for a circuit and equipment developmental program for the Armed Services. This department evolved into a manufacturing plant in 1942 and in July of that year he was appointed plant manager. In the Spring of 1944 this plant was moved to Williamsport, Pennsylvania.

Mr. Graham has been chairman of the Rochester Fall Meeting Committee since its inception in 1929. He joined the Institute in 1924 as an Associate, became a Member in 1927, and a Fellow in 1935. During his membership he has held many committee appointments and was a member of the Board of Directors from 1935 to 1941. He became a Member of the Institution of Radio Engineers, Australia, in 1936 and was awarded a Fellowship in that organization in 1941. He is a member of the Acoustical Society of America, the Society of Illuminating Engineers, the Société des Radioélectriciens, and the Rochester Engineering Society.

Radio Progress During 1945*

Introduction

THE YEAR 1945, with the cessation of hostilities, saw the beginning of publication of information about some of the uses to which radio communication systems and related techniques had been put during the war years.

The gradual relaxation in military restrictions has resulted in the revelation of some new advances, either by implication or through semitechnical papers, although security reasons have, to some extent, still held back the publication of many interesting and significant developments. It seems probable that, with the publication of fuller technical details, it will become possible to include more of these developments in next year's review. The year 1946 should see a volume of technical publications of outstanding interest.

During the last half of the year, radio engineers have been devoting major attention to the problems of applying the most advanced technical knowledge to the requirements of peacetime commercial activities.

Striking developments which have been disclosed in general terms but which have not yet been fully covered in technical publications are various applications of pulse methods of radio transmission, such as radar systems of many types and a system of navigational aids known as "loran."

During the year, the Federal Communications Commission continued with the holding of hearings on frequency allocation begun in 1944. As a result, the Commission issued a report on May 25, 1945, supplemented on June 27, 1945 and on November 19, 1945, allocating frequency bands in the range of 25 megacycles to 30,000 megacycles to radio services in the United States. In this portion of the spectrum, comparatively new to practical utilization, allocations were made for frequency-modulation broadcasting and television broadcasting and for many new services including telephone communication with mobile units, such as trucks, busses, taxicabs, and railroad rolling stock, radio-relay systems, aviation-radio devices, civilian two-way radio telephony, and for medical and industrial electronic applications. The Commission, on May 21, 1945, issued a proposed reallocation of frequency bands in the range of 10 to 25,000 kilocycles.

Radio Transmitters

Activity in the field of radio transmitters for commercial and civil applications was greatly stimulated coincident to the ending of the war. The extensive research and development of electronic circuits and vacuum tubes for military use during the war were already giving rise, before the close of 1945, to new and promising transmitting-apparatus designs.

Renewed interest was being expressed in the use of transmitter powers greater than 50 kilowatts for amplitude-modulation broadcasting. Several new transmitter developments for frequency-modulation broadcasting at power levels ranging from 250 watts to 50 kilowatts were announced as a result of the reallocation of the frequency-modulation broadcast band to the region of 100 megacycles. Transmitters for television broadcasting in the channels below 90 megacycles were being manufactured by several suppliers and the development of television transmitters for operation in the region of 200 megacycles was going forward with accelerated interest. Much activitity and interest was developing over the possibilities of pulse-position or pulse-time-modulated transmitters for point-to-point and radio-relay transmission at microwave lengths, and several experimental installations were being made.

TABLE I

RADIO BROADCAST STATIONS FOR WHICH LICENSES AND CONSTRUCTION PERMITS ISSUED BY THE FEDERAL COMMUNICATIONS COMMISSION WERE OUTSTANDING ON DECEMBER 31, 1945

Class of Broadcast Station	Number of Licenses and Construction Permits
Standard	1004
Commercial high-frequency (frequency-modulation)	282*
Experimental high-frequency	1
Commercial television	9
Experimental television	54
International	38
Facsimile	3
Noncommercial educational	15
Developmental	38

* Including 229 conditional grants.

Many instructive papers dealing with radio transmitters appeared throughout the year 1945.

A twelve-channel radio multiplex circuit spanning the Chesapeake Bay and comprising a part of the network of the Chesapeake and Potomac Telephone Company, installed in 1941, was described in four papers; viz,

(1) N. F. Schlaack and A. C. Dickieson, "Cape Charles-Norfolk ultra-short-wave multiplex system," PROC. I.R.E., vol. 33, pp. 78–83; February, 1945.
(2) Charles R. Burrows and Alfred Decino, "Ultra-short-wave multiplex," PROC. I.R.E., vol. 33, pp. 84–94; February, 1945.
(3) D. M. Black, G. Rodwin, and W. T. Wintringham, "Ultra-short-wave receiver for the Cape Charles-Norfolk multiplex radiotelephone circuit," PROC. I.R.E., vol. 33, pp. 95–100; February, 1945.
(4) R. J. Kircher and R. W. Friis, "Ultra-short-wave transmitter for the Cape Charles-Norfolk multiplex system," PROC. I.R.E., vol. 33, pp. 101–106; February, 1945.

A feature of the transmitter of especial interest was the design of the circuit employing 40 decibels of envelope feedback, the basic method of feedback design, and the

* Decimal classification: R090. Original manuscript received by the Institute, January 30, 1946. This report is based on material from the 1945 Annual Review Committee of The Institute of Radio Engineers, as co-ordinated and edited by Laurens E. Whittemore, Keith Henney, H. A. Wheeler, I. S. Coggeshall, and J. Warren Horton.

technique of practical application was given in considerable detail.

In one paper the desirability of specifying quartz crystals in terms of their intrinsic properties, instead of the desired performance of the set, was stressed and contrasted with present practice.

(5) K. S. VanDyke, "The standardization of quartz-crystal units," PROC. I.R.E., vol. 33, pp. 15–20; January, 1945.

When it becomes the practice to use circuit properties of crystals, when convenient instruments for impedance measurement are available, and when formal treatment of oscillator-circuit design is extended to include crystal-controlled types, there will naturally follow the convenient cataloging and standardization of a relatively few types.

An improved amplifier for single-sideband transmission of one or two channels was described.

(6) C. F. P. Rose, "A 60-kilowatt high-frequency transoceanic-radiotelephone amplifier," PROC. I.R.E., vol. 33, pp. 657–662; October, 1945.

Of interest is the means described for the rapid change of frequency between assigned frequencies within the range from 4.5 to 22 megacycles.

Circuit features, typical operating conditions, and distortion characteristics were given for an experimental triode amplifier operating at 140 megacycles.

(7) R. J. Kircher, "A coil-neutralized vacuum tube amplifier at very high frequencies," PROC. I.R.E., vol. 33, pp. 838–843; December, 1945.

A survey of multichannel communication systems which make use of modulated pulse change was given in one paper.

(8) F. F. Roberts and J. C. Simmonds, "Multichannel communication systems," *Wireless Eng.*, vol. 22, pp. 538–549; November, 1945; pp. 576–580; December, 1945.

The principles underlying the system were considered at some length and the advantages as compared with conventional multichannel systems were discussed. Experimental apparatus employing amplitude-modulated pulses was described which gave seven good-quality speech channels in a bandwidth of 110 kilocycles.

In one paper,

(9) "PT modulation for multiple transmission," *Electronic Indus.*, vol. 4, pp. 90–91; November, 1945,

a system was described whereby the time of occurrence of carrier pulses is advanced for positive and retarded for negative portions of the signal wave. This method permits the transmission of intelligence by means of a series of pulses of about one-half-microsecond duration, each separated from the other by a time interval of about 5 microseconds. Their time of recurrence can be advanced or retarded over a range of approximately one microsecond. Converting the modulated pulses to amplitude modulation is accomplished by means of a cyclophone which is similar to a cathode-ray tube except that the target end of the tube has a metal plate with radially disposed slits behind which is another plate which is the target for the cathode ray.

A system of pulse-position modulation was described in which, by clipping sine waves into square form, altering their length and differentiating, pulses are obtained at varying times.

(10) "Pulse position modulation technique," *Electronic Indus.*, vol. 5, pp. 82–87, and 180, 182, 184, 186, 188, 190; December, 1945.

The radio transmitter converts position-modulated positive impulses derived from transmitting multiplex equipment into impulses of ultra-high-frequency power. The final wave form of the radiated ultra-high-frequency impulses may be pictured as a series of eight groups of 5000-megacycle oscillations each emitted from the antenna for a period of approximately 1 microsecond, plus a 4-microsecond marker impulse. For the production of a wave shape of this type, the transmitter included an ultra-high-frequency oscillator excited by momentary power impulses from a modulator.

The following summarizes the explanation of pulse-time modulation given in one paper.

(11) E. M. Deloraine and E. Labin, "Pulse time modulation," *Elec. Commun.*, vol. 22, pp. 91–98; 1944.

Pulse-time modulation consists essentially in the transmission of signals by pulses of constant amplitude, the instantaneous amplitude of the voice being translated into a variation of time intervals of successive pulses; the rate of this variation corresponds to the instantaneous frequency of the signal period. Important advantages include improvement of the signal-to-noise ratio as the bandwidth increases and the possibility of adding repeaters without increasing distortion. Thus this method of modulation appears particularly promising for application to multichannel radio and coaxial-cable transmission systems and to ultra-high-frequency broadcasting and television sound channels. High spots relating to the conception and development of pulse-time modulation were included in the paper to complete the historical record.

Technical details of the radio station at Delano, California, for putting three short-wave broadcast programs on the air simultaneously were given in a paper by

(12) Robert N. DeHart, "OWI-CBS 200-kw west coast transmitters," *Electronic Indus.*, pp. 82–85, 148, 150, 152, 154, 156; April, 1945.

A high-power radio-frequency converter designed for use with frequency-modulated broadcast transmitters permitting operation in either one of two frequency bands or simultaneous operation in both bands was described in a paper by

(13) Frank A. Gunther, "Power frequency converter for FM," *FM and Television*, vol. 3, pp. 53–54, 78–79; August, 1945.

One paper described 250-, 1000-, and 3000-watt frequency-modulation broadcast transmitters for operation in the 88- to 108-megacycle band. The transmitters employed reactance control tubes as modulators, electromechanical control of the center frequency independent of the modulation action, and grounded-grid power amplifiers.

(14) C. M. Lewis, "Data on RCA FM broadcast equipment," *FM and Television*, vol. 5, pp. 28–35; November, 1945.

The Signal Corps of the United States Army has described a world-wide communication network utilizing a multichannel radiotelegraph system of which noteworthy features are stability of transmission and economy of frequency utilization.

(15) "Army Service Forces, Annual Report for fiscal year, 1945," pp. 42–43.
(16) Major General Harry C. Ingles, Chief Signal Officer, U. S. Army, "Electrical communications in world-wide warfare—I. On the ground," *Bell Tel. Mag.*, vol. 24, pp. 54–72; Summer, 1945.

Frequency Modulation

During 1945 the developments in frequency modulation moved ahead very rapidly, first in anticipation of the end of the war, and later through reconversion programs. Early in the year, intense discussions took place between industry and the Federal Communications Commission in the United States to determine frequency allocations to be made, among other services, for frequency-modulation broadcasting. An outstanding series of discussions of radio-transmission considerations as bearing on the frequency-allocation problem took place at the I.R.E. Winter Technical Meeting in January, 1945. These discussions have been reproduced as a special pamphlet by the Institute. The Federal Communications Commission, in August, made definite frequency allocations for frequency-modulation broadcasting, designating the band from 88 to 92 megacycles for educational and noncommercial frequency-modulation broadcasting, and designating the band from 92 to 106 megacycles for commercial frequency-modulation broadcasting. At the end of the year the industry was applying itself at top speed to make available both receivers and transmitters for use in this new band.

One paper published during the year emphasized the availability of broad-band telephone systems to produce high-fidelity transmission, on many routes providing an 8000-cycle band, and on routes utilizing types J, K, and L carrier systems providing a 15,000-cycle band. Thus the frequency-modulation broadcasters will be able to operate networks with high fidelity when desired.

(17) H. S. Osborne, "Transmission networks for frequency modulation and television," *Elec. Eng.*, vol. 64, pp. 392–397; November, 1945.

At the end of 1944, further developments in the use of a synchronized oscillator as a combined limiter and amplifier were reported. This locked-in oscillator type of circuit seems destined to influence the design of frequency-modulation receivers.

(18) G. L. Beers, "A frequency-dividing locked-in oscillator frequency-modulation receiver," Proc. I.R.E., vol. 32, pp. 730–737; December, 1944.

One of the serious problems in the design and operation of frequency-modulation broadcast receivers has been the difficulty in accurately stabilizing the frequency to which the receiver is tuned. A relatively inexpensive design of a crystal-controlled frequency-modulation receiver has been developed. The use of this receiver essentially eliminates this problem.

(19) William Maron, "Crystal-tuned F-M receivers," *Electronics*, vol. 18, pp. 138–141; October, 1945.

The planning and construction of a new 50-kilowatt frequency-modulation transmitter has been reported in considerable detail. This report presents a convenient reference for the many individuals about to plan for new frequency-modulation stations. The frequency shift to the new allocations introduces a variation in the problems, but fundamentally the problems are similar.

(20) P. B. Laeser, "Planning an F-M station," *Electronics*, vol. 18, pp. 92–97; February, 1945.
(21) P. B. Laeser, "A 50-kw F-M transmitter," *Electronics*, vol. 18, pp. 100–105; April, 1945.

With the design of frequency-modulation antennas for use by broadcasters who are already operating transmitters in the standard broadcast range, a special square-loop antenna together with an insulated antenna coupler has been developed which allows the standard insulated tower to be used as the support for the frequency-modulation antenna. Using the new design, the reduced wind resistance allowed in one case the saving of 150 feet in antenna height, as compared with the flag pole which would have been required with a corresponding six-layer turnstile antenna. The resultant antenna gain was even better than that obtainable from the turnstile.

(22) J. P. Taylor, "A square-loop F-M antenna," *Electronics*, vol. 18, pp. 96–100; March, 1945.
(23) J. P. Taylor, "F-M antenna coupler," *Electronics*, vol. 18, pp. 107–109; August, 1945.

The development of a radio-relay system for television using frequency-modulation has been announced. Frequency-modulation has the distinct advantage, in this work, of allowing limiting action at each station, and of reducing the noise level per station below that encountered when amplitude modulation is used. Since signal-to-noise ratio is the primary limiting factor in determining the maximum distance between stations, a distinct advantage is gained by the use of frequency-modulation in this application.

(24) C. W. Hansell, "Radio-relay-systems development by the Radio Corporation of America," Proc. I.R.E., vol. 33, pp. 156–168; March, 1945.

A proposal has been made to develop a duplex communication system involving frequency-modulation and using the transmitter oscillator at one terminal as the local oscillator of a superheterodyne at that same terminal. Thus the transmission in one direction is carried at a frequency differing from the frequency of transmission in the opposite direction by the intermediate frequency of the receivers.

(25) E. E. Suckling, "A stabilized narrow-band frequency-modulation system for duplex working," Proc. I.R.E., vol. 33, pp. 33–35; January, 1945.

The work has continued on investigation of the transmission of frequency-modulation signals through tuned

circuits and on the degree of interference between two frequency-modulation signals having the same carrier frequency. It is found experimentally that, for negligible distortion to a 15,000-cycle signal, the ratio of the peak frequency swing to the bandwidth at the half-power point should be equal to one quarter.

(26) David Lawrence Jaffe, "A theoretical and experimental investigation of tuned-circuit distortion in frequency-modulation systems," PROC. I.R.E., vol. 33, pp. 318–333; May, 1945. (Corrections, pp. 482; July, 1945.)
(27) R. N. Johnson, "Interference in F-M receivers," *Electronics*, vol. 18, pp. 129–131; September, 1945.

In general, 1945 has been a year of preparation for a most rapid future advance in the field of frequency modulation.

Radio Receivers

The ending of the war in August, 1945, brought an immediate and widespread change in both engineering and production from receivers for military and naval applications to receivers for civilian use.

Despite the fact that War Production Board limitation orders were rapidly withdrawn following the war's end, by the end of the year the total production volume in the United States, in the four months during which civilian production was permitted, amounted to only about 300,000 receivers, or less than 2 per cent of conservative estimates for production expected in the first entire postwar year. This low rate of production was due primarily to a shortage of component parts, which shortage was, in turn, caused principally by parts-manufacturers' belief that the prices originally permitted for their products were too low to permit economic manufacture, and secondarily, towards the close of the year, by labor unrest.

The end of the war also brought a lifting of restrictions on publication of technical information on wartime uses of radio, and papers describing those uses began to appear in the technical literature. Many of those uses involved complete systems of transmission so that the papers dealt only in part with the receiver portion of the systems. Among such papers were descriptions of radar equipment; the long-range navigation system known as "loran"; the proximity fuze; and other specialized military applications of radio techniques.

(28) "The SCR-268 radar," *Electronics*, vol. 18, pp. 100–109; September 1945.
(29) "The SCR-584 radar," *Electronics*, vol. 18, pp. 104–109; November, 1945; pp. 104–109; December, 1945.
(30) "Radar specifications," *Electronics*, vol. 18, pp. 116–119; November, 1945.
(31) "The loran system," *Electronics*, vol. 18, pp. 94–99; November, 1945.
(32) "Proximity fuze," *Electronics*, vol. 18, pp. 110–111; November, 1945.
(33) Daniel E. Noble, "Details of the SCR-300 F-M walkie-talkie," *Electronics*, vol. 18, pp. 204, 209, 212, 216; June, 1945.
(34) Harry Stockman, "UHF converter analysis", *Electronics*, vol. 18, pp. 140–143; February, 1945.

The widespread use of piezoelectric crystals during wartime led to their more general consideration than heretofore as components in peacetime receivers. In general, a quartz crystal was used to control the frequency of the heterodyne oscillator, and such use may become important in applications where the added cost of such crystals is not a deterrent, such as in high-quality frequency-modulation, television, and communication receivers. A compact two-channel diversity receiver was described, in which the heterodyne-oscillator frequency is determined by the combination of the outputs of a crystal-controlled and a variable-frequency oscillator. Improvement in oscillator stability by design improvements in components also received attention.

(35) William Maron, "Crystal-tuned F-M receivers," *Electronics*, vol. 18, pp. 138–141; October, 1945.
(36) Sidney X. Shore, "Crystal oscillators in F-M and television," *Communications*, vol. 25, pp. 50, 52, 54, 83–86; August, 1945. (Part one of a series.)
(37) J. G. Nordahl, "Tank radio set," *Bell Labs. Rec.*, vol. 23; pp. 1–5; January, 1945.
(38) H. A. Ross and L. K. Curran, "Some developments in crystal-controlled diversity receivers," *A.W.A. Tech. Rev.*, vol. 6, pp. 337–349; March, 1945.
(39) John B. Moore, "Design of stable heterodyne oscillators," *Electronics*, vol. 18, pp. 116–118; October, 1945.

Rectifying crystals also received attention due to their use as frequency converters in ultra-high-frequency superheterodyne receivers. The design and performance have been covered with applications to radar noted. In addition, the theory of rectification was given in terms of the work function of conductors and semiconductors.

(40) Arthur C. Gardner, "Rectifying crystals," *Radio*, vol. 29, pp. 48–50, 68, 69; August, 1945.
(41) Harry Stockman, "UHF converter analysis," *Electronics*, vol. 18, pp. 140–143; February, 1945.

Frequency-modulation reception techniques were given increasing attention. The design of the intermediate-frequency amplifier was discussed as was the problem of distortion introduced by both single- and double-tuned circuits.

(42) William H. Parker, Jr., "The design of an intermediate-frequency system for frequency-modulated receivers," PROC. I.R.E., vol. 32, pp. 751–753; December, 1944.
(43) David Lawrence Jaffe, "A theoretical and experimental investigation of tuned-circuit distortion in frequency-modulation systems," PROC. I.R.E., vol. 33, pp. 318–333; May, 1945. (Corrections, p. 482; July, 1945.)

A new detector for frequency-modulated waves with inherent limiting qualities within the detection process was described.

(44) S. W. Seeley, "Ratio detectors for frequency-modulation receivers," presented, New York Section, October 3, 1945, New York, N. Y.

A receiving system and the various parts of the receiver were described, in which harmonic distortion produced by fading of the carrier with respect to the sidebands is eliminated. Results of observations of reception on an exalted-carrier diversity receiving system were given.

(45) Murray G. Crosby, "Exalted-carrier amplitude- and phase-modulation reception," PROC. I.R.E., vol. 33; pp. 581–591; September, 1945.

The problem of receiver noise received further attention from the standpoint of the input circuit and with regard to the effects of automatic gain control.

(46) R. E. Burgess, "Signal-to-noise characteristics of triode input circuits," *Wireless Eng.*, vol. 22, pp. 56–61; February, 1945.
(47) John B. Moore, "AGC-noise considerations in receiver design," *Electronics*, vol. 18, pp. 116–118; May, 1945.

Several novel types of superheterodyne receivers were described during the year. One type in which tuning to any broadcast channel is accomplished solely by push-buttons was described and demonstrated at the I.R.E. 1945 Winter Technical Meeting. Interest in the design of superheterodyne receivers with an intermediate-frequency higher than the received frequency was revived. A novel method of obtaining some new capabilities from the superheterodyne receiver has recently been described. It employs a triple-detection receiver, each of the fixed-tune amplification channels being given an infinite-rejection characteristic on one side. Thus, by varying the frequency of the second beating oscillator, the admittance band is varied from very wide down to zero. New noise-rejection possibilities are obtained in continuous-wave reception when the bandwidth is made zero and the desired signal swept periodically into an acceptance band by frequency modulation of the second beating oscillator at audio frequency.

(48) John D. Reid, "I.R.E. Winter Technical Meeting," *Electronics*, vol. 18, pp. 318, 320; March, 1945.
(49) Harvey Kees, "Receiver with 2 Mc. I.F.," *Electronics*, vol. 18, pp. 129–131; April, 1945.
(50) Dana A. Griffin, "Griffin triple detection superhet," *CQ*, vol. 1, pp. 11–14, 38–39; May, 1945.

A radiation method for sensitivity calibration of receivers at frequencies above 30 megacycles employed calculations of the field at the receiving antenna due to current in the transmitting antenna.

(51) J. S. McPetrie, W. E. Perry, and L. H. Ford, "Sensitivity calibration of receivers," *Wireless Eng.*, vol. 22, pp. 6–13; January, 1945.

The requirements and design of a receiver for use in multiplex radiotelephony, which employed many interesting principles, were discussed. The receiver is a triple-detection type designed to work in the radio-frequency spectrum between 150 and 160 megacycles.

(52) D. M. Black, G. Rodwin, and W. T. Wintringham, "Ultra-short-wave receiver for the Cape Charles-Norfolk multiplex radiotelephone circuit," PROC. I.R.E., vol. 33, pp. 95–100; February, 1945.

Electron Tubes

Large High-Vacuum Tubes

Relatively very few papers dealing directly with development of power-output electron tubes were published in the technical literature in the United States during the period from December, 1944, to November, 1945. Still less could be found in the fragments of literature published in other countries which reached the United States during this period. However, the termination of the war has permitted disclosure of several developments which during the war were classified as "secret" or "confidential." Up to the time of writing this report, not many papers have been published on the subject of power-output vacuum tubes specially designed for war applications. Nevertheless, in a number of public lectures some interesting features of such special tubes have been revealed directly or by implication, as subjects were being taken off the classified list.

Most important and interesting from the engineering viewpoint is the development of electron tubes for radar. Specific features of their designs resulted from the character of radar operation. The most important demand was to deliver the generated radio-frequency energy to the antenna in extremely short but powerful pulses spaced by relatively large time intervals. Therefore, the operating voltages used even on small tubes for this operation are up to 15,000 or 20,000 volts. Then, in order further to increase the peak power, the cathode emission was to be as high as could be made. Hence, attempts were made to use generously dimensioned thoriated-tungsten filamentary cathodes or indirectly heated oxide-coated cathodes even with the specified high operating voltages. This was contrary to the designers' common prejudice against the use of activated cathodes at voltages above 4000 volts. However, the vast experience fully justified use of activated cathodes under the condition of pulse operation.

Instantaneous power output in radar tubes exceeds many times the normal maximum power output from tubes of the same size in ordinary continuous-wave amplitude- or frequency-modulation operation. The average power naturally depends on pulse width (from 10 microseconds to a fraction of a microsecond) and frequency of pulsing (from 200 to several thousands per second). It is limited not only by the permitted anode and grid dissipation, but also by cathode dissipation, as the cathodes are in some types of tubes subject to severe electron bombardment.

General design and structural details of the radar tubes comply with the frequency to be generated. For frequencies from 100 to 300 and even 600 megacycles used in the long-range radar installations, specially designed triodes proved to be satisfactory.

A series of special radar triodes was developed shortly before and during the war, known as 15E, 127A, VT-158, 227A, 327A, 527, 434A, 530, etc. Also British types were manufactured in this country, designated VT-31, VT-90, VT-98, VT-99, and VT-114. Many of these tubes have thoriated-tungsten cathodes; the VT-99 and 527 have oxide-coated cathodes. The possible peak power output depending on emission and duty cycle ranges from 5 kilowatts per tube to more than one megawatt.

(53) Roger B. Colton, "Radar in the United States Army," PROC. I.R.E., vol. 33, pp. 740–753; November, 1945.
(54) "The SCR-268 radar," *Electronics*, vol. 18, pp. 100–109; September, 1945.
(55) "Radar specifications," *Electronics*, vol. 18, pp. 116–119; November, 1945.
(56) I. E. Mouromtseff, "Electronics and development of electronic tubes," *Jour. Frank. Inst.*, pp. 171–192; September, 1945.

An outstanding war development in the line of power tubes was the resonant or multicavity magnetron. It received early attention in Great Britain, and in general its features somewhat resemble the Russian

magnetron mentioned in last year's report. Enormous contribution to the final design and manufacturing methods of the resonant magnetron has been made by various organizations in the United States. These magnetrons were designed for operation in the ship, plane, and gun-fire-control radar systems on frequencies from 600 megacycles up to above 10,000 megacycles (from 50-centimeter to less than 3-centimeter wave length). These tubes are made of a block of solid copper with a central cylindrical chamber (interaction space) with an axially mounted oxide-coated cathode and with several resonance cavities arranged in a circle around and opening into the central chamber. Usually these tubes are cooled by air blast.

With dimensions approximately $1\frac{1}{2}$ inches long and 2 inches in diameter, these tubes are capable of producing peak power output of several hundred or even a thousand kilowatts. Hundreds of thousands of such magnetrons were manufactured during the war in this country. Undoubtedly, various aspects of this marvelous development will be discussed in the technical literature during the next year.

(57) "Radar specifications," *Electronics*, vol. 18, pp. 116–119; November, 1945.

Another war development was that of "jamming" tubes for making the enemy's radar ineffective. One of these tubes was the "resnatron," developed in the United States under the auspices of Office of Scientific Research and Development. The resnatron is a water-cooled tetrode with built-in oscillating circuits in the form of cavity resonators. In continuous-wave operation it is capable of developing more than 50 kilowatts output power at 600 megacycles. Another development in the same field was a series of split-plate magnetrons for continuous-wave operation, covering a wide range of frequencies.

An important factor in all types of "microwave tubes," used in radar and also in other ultra-high-frequency applications, is the elimination of discontinuity between the tube electrodes and the oscillating circuit.

A thorough application of this idea to the triode permitted extension of the usefulness of this type of tube up to 600 megacycles with most unexpectedly high outputs. Representative of this type of tube is one capable of supplying 75-kilowatt peak power described in a paper by Major Zahl and Dr. Gorham at the 1945 Winter Technical Meeting; also the Sloan tube, the "resnatron," previously mentioned, with more than 50 kilowatts in continuous-wave operation at the specified frequency. A third tube of similar type is one delivering a peak power of 500 kilowatts at 400 megacycles. This tube is a combination of two triodes in a push-pull arrangement with cylindrical cavity resonators between them. The characteristic feature of all these tubes is making the tube elements part of the oscillating circuits inherently attached to the tube and placing them in the same vacuum enclosure. Useful power is then taken outside by a suitable transmission line coupled to one of the internal oscillating circuits.

It is interesting to note that in a paper in foreign literature, a split-plate magnetron is described having a grid by means of which the output can be modulated.

(58) C. J. Brawde and A. M. Ivanenko, "Magnetron with grid control and some of its applications in the band of medium u-h-f and decimeter waves," *Jour. Tech. Phys.*, vol. 14, pp. 611–622; September–October, 1944.

Among other radar developments, tubes of the "lighthouse" type also have been described.

(59) E. D. McArthur, "Disc seal tubes," *Electronics*, vol. 18, pp. 98–102; February, 1945.

In connection with the development of radar systems, a "pulse-modulator" tube type came into use. Its function is the abrupt opening and stopping of the flow of the direct-current power to the radio-frequency oscillator tube during each cycle and withholding this power from reaching the oscillator during the intervals between the successive pulses. The necessary characteristics of the pulse-modulator tubes are (1) ability to pass very high currents during time intervals of several microseconds or a fraction of a microsecond; (2) low internal voltage drop even at the maximum pulse current; (3) ability to bar direct-current power supply at approximately 10 to 15 kilovolts from finding its way to the oscillator; (4) convenience of triggering the direct-current power to give the desired pulse shape. Both triodes and tetrodes were developed for this purpose, tetrodes having the advantage of greater "power gain."

In the frequency band from 500 to 1000 megacycles, new small triodes capable of delivering powers up to 500 watts at 600 megacycles, and reduced power up to 1000 megacycles, have been developed by one of the electron-tube manufacturers. These tubes can be cooled either by forced-air or by water. Several other newly designed tetrodes have also been announced by various manufacturers in connection with the pending development of television and frequency modulation. For frequencies up to 120 megacycles, radiation-cooled tetrodes are available with approximately 350 watts and up to 70 megacycles with 750 watts output. At the November, 1945, I.R.E.-R.M.A. meeting at Rochester, an outstanding development of a 5-kilowatt push-pull tetrode which is satisfactory to at least 300 megacycles was described. This tube uses water-cooling of all supporting members and the anodes, resulting in a structure with very low capacitances.

The development of power-output tubes for industrial application continued mainly in the frequency range below 30 megacycles for dielectric heating. Frequencies of 13.6 and 27.66 were specially allocated by the Federal Communications Commission for such use. Some of these tubes with reduced output, or specially designed triodes of various makes intended for frequencies up to 100 megacycles, are gradually appearing on the market. They are preponderantly of the forced-air-cooled type with plate ratings up to 2500 watts. The same tubes

may perhaps be employed in frequency-modulation sets in the 88- to 108-megacycle band newly assigned for this purpose. In this latter case, the tubes may be operated in grounded-grid circuits.

(60) Clayton E. Murdock, "VHF tetrode for medium output power," *FM and Television*, vol. 5, pp. 20–21; February, 1945.

In the field of power-output tubes for intercontinental broadcasting, some transmitters have employed new tubes capable of delivering 100 kilowatts each at 22 megacycles.

(61) Hugo Romander, "Engineering details of OWI 200-kw units," *Electronic Indus.*, vol. 4, pp. 100–103, 158, 162; October, 1945.

Among other developments for broadcast service, it is worth mentioning that favorable experience with high-output radar tubes having thoriated filaments and operated at 15 kilovolts on the plate, accelerated the development of several more or less successful experimental tubes with similar cathodes. There is an indication, but no full assurance, that these tubes will immediately be able to compete with the standard water-cooled tubes with pure-tungsten cathodes.

It is also worth mentioning that, as an outcome of war development, intensive study of secondary-emission cathodes in power tubes, mainly of the magnetron type, has been carried out.

Another improvement in power-output tubes, which steadily finds its way into tube design, is replacing the standard cathode presses by glass dishes supporting inner-tube structure as the technique of making dishes improves. This permits shortening the tube structural parts, thus extending the tube frequency limit upwards.

Continuation of work on materials for grids of high-power tubes has resulted in another nonemitting grid material.

(62) Harold E. Sorg and George A. Becker, "Grid emission in vacuum tubes," *Electronics*, vol. 18, pp. 104–109; July, 1945.

From the reviews published in other countries, which became available in the United States during 1945, one cannot draw much information regarding the power-output tube development progress in Europe. However, this interesting remark can be made. Several years ago (up to 1942) a large European firm was strongly advocating demountable types of high-vacuum tube with continuous exhaust in operation in preference to the sealed-off type even for smaller sizes, with 5- or 19-kilowatt output ratings. A suggestion has even been made for application of demountable high-vacuum tubes as "mutators" (in our terminology, "invertors") instead of mercury-pool tubes in high-voltage direct-current power-transmission installations. In a few available issues of one publication for 1945, the same firm now promotes sealed-off tubes even for the 50-kilowatt size.

(63) A. Gaudenzi, "High-power demountable transmitting tubes," *Brown Boveri Rev.*, vol. 28, pp. 389–393; December, 1941.

(64) A. Gaudenzi, "High-vacuum mutators for direct-current transmission," *Brown Boveri Rev.*, vol. 28, pp. 319–322; October, 1941.

(65) F. Jenny, "Sealed-off transmitting tubes and their production," *Brown Boveri Rev.*, vol. 33, pp. 309–312; September, 1944.

Small High-Vacuum Tubes

The expanded production in the United States, required primarily for military purposes, is indicated by the following comparative figures. The large increase in dollar values on electron tubes as compared with the number of units is a reflection of an increasing proportion of closer spaced and more complex tubes as well as of increased production costs.

TABLE II

	1939 Average Monthly Production	June, 1945, Deliveries
Receiving tubes	9,127,000 units	13,117,000 units
Receiving tubes	$2,747,000	$6,380,000
Transmitting tubes	27,000 units	2,412,000 units
Transmitting tubes	$189,000	$15,860,000
Transformers	$706,000	$12,090,000
Capacitors	$2,298,000	$12,023,000
Resistors	$710,000	$4,429,000

Radio and Radar Information Letter, issued by United States Government War Production Board, September, 1945, p. 1.

An interesting summary of the developmental history of all classes of vacuum tubes was made available.

(66) I. E. Mouromtseff, "Development of electronic tubes," PROC. I.R.E., vol. 33, pp. 223–233; April, 1945.

Possibly the best available picture of the progress of tube development and production during the war is shown by the listing of certain types of tubes on the United States Government's Joint Army-Navy Preferred List together with typical characteristics given in the accompanying table. These are the types used for new designs for service equipment unless other types were especially authorized. Hundreds of other tube types were still being procured at the end of the war.

(67) Army-Navy Preferred List of Radio Electron Tubes, September 15, 1944.

One of the wartime requirements was for tubes of increased resistance to shock and extreme vibration due to gunfire, engine vibration, etc. Specifications for the first of such tubes became available for public reference.

(68) Joint Army-Navy Specifications JAN-1A, pp. JAN-6AC7W (January 15, 1945) and JAN-6SN7W (June 30, 1945).

Still another outstanding development was miniature electron tubes for proximity fuzes (which replaced time fuzes in the head of shrapnel-like projectiles). These tubes are the smallest in existence. Their over-all length, including the base, is slightly over one inch and their rectangular cross section approximately $\frac{3}{8}'' \times \frac{1}{4}''$. Within such a space, triode, tetrode, or pentode structures are located. Each proximity fuze employs several miniature tubes some of which perform the duty of real "power-output" tubes although their output is measured in only a few milliwatts (up to 25). The outstanding feature of these tubes, besides being the smallest power-output tubes ever built, is the mechanical design which

TABLE III
JOINT ARMY-NAVY PREFERRED TUBES
(United States Government)

Triodes

	Ef	Eb	Ec	If	Ib	Mu	Gm	
1LE3	1.4	90	−3	0.050	1.4	14.5	760	
2C22	6.3	300	−10.5	0.3	11	20	3000	
2C40*	6.3	250	−3.3	0.75	16.5	36	4800	("light-house")
6AQ6*	6.3	250	−3	0.15	1.0	70	1200	(two diodes)
6C4*	6.3	250	−8.50	0.15	10.5	17	2200	
6F4*	6.3	80	−20	0.225	13	17	5800	
6J4*	6.3	150		0.4	15	55	12000	
6J5, 6J5GT	6.3	250	−8	0.3	9.0	20	2600	
6SQ7, 6SQ7GT	6.3	250	−2	0.3	0.9	100	1100	(two diodes)
6SR7, 6SR7GT	6.3	250	−9	0.3	9.5	16	1900	(two diodes)

Twin Triodes (each section)

3A5*	1.4	90	−2.5	0.22	3.7	15	1800	
6J6*	6.3	100	−.85	0.45	8.5	32	5300	
6SL7GT	6.3	250	−2	0.3	2.3	70	1600	
6SN7GT	6.3	250	−8	0.6	9	20	2600	
7F8*	6.3	250	−2.5	0.3	10	52	5000	

Pentodes

	Ef	Eb	Ec2	Ec1	If	Ib	Gn	Rp	
1L4	1.4	90	67.5	0	0.05	2.9	925	0.6	
1LN5	1.4	90	90	0	0.050	1.6	800	1.1	
1S5	1.4	90	90	0	0.050	2.7	720	0.5	(one diode)
6AB7	6.3	300	200	−3	0.45	12.5	5000	0.7	
6AC7	6.3	300	150	−2	0.45	10	9000	1.0	
6AG7	6.3	300	150	3.0	0.65	30	11000	0.13	
6AJ5*	6.3	28	28		0.175	3.0	2750	0.09	
6AK5*	6.3	180	120	−2	0.175	7.7	5100	0.69	
6AS6*	6.3	120	120	−2	0.175	5.8	3500	—	
6SG7*	6.3	250	150	−2.5	0.3	9.2	4000	over/1.0	
6SJ7, 6SJ7GT	6.3	250	100	−3	0.3	3.0	1650	over/1.0	
6SK7, 6SK7GT	6.3	250	100	−3	0.3	9.2	2000	0.8	
7W7	6.3	300	150		0.45	10	5800	0.3	
9001	6.3	250	100	−3	0.15	2.0	1400	over/1.0	
9003	6.3	250	100	−3	0.15	6.7	1800	0.7	

Converters

	Ef	Eb	Esg	If	Ik	Ib	Gc	
1LC6	1.4	90	35	0.050	2.9	0.75	275	(pentagrid)
1R5	1.4	90	67.5	0.05	5	1.7	300	(pentagrid)
6SA7, 6SA7GT	6.3	250	100	0.3	12.5	3.5	450	(pentagrid)
14J7	12.6	250	100	0.15	10.0	1.3	300	(triode-hexode)

Output Tube

	Ef	If	Eb	Ec2	Ec1	Ib	Ic2	Gm	P.O. Watts	
1LB4	1.4	0.5	90	90	−9	5.0	1.0	925	0.2	
3A4*	1.4	0.2	150	90	−8.4	13.3	2.2	1900	0.7	
3S4	1.4	0.1	90	67.5	−7	7.4	1.4	1575	0.27	
6B4G	6.3	1.0	250		−45	60		6250	3.2	(one triode)
6G6G	6.3	0.15	180	180	−9.0	15.0	2.5	2300	1.1	
6L6GA	6.3	0.9	350	250	−18	54	2.5	5200	10.8	
6N7GT	6.3	0.8	294		−6	7		3200	10.0	
6V6GT	6.3	0.45	315	225	−13	34	2.2	3750	5.5	
6Y6G	6.3	1.25	200	135	−14	61	2.2	7100	6.0	
12A6	12.6	0.15	250	250	−12.5	30	3.5	3000	3.4	
25L6GT	25.0	0.3	200	110	−8	50	2.0	9500	4.3	
28D7*	28.0	0.4	28	28	−3.5	12.5	1.0	3000	0.1	(each section)

Diodes and Rectifiers (Vacuum Types)

	Ef	If	Ib	Maximum Peak Inverse Eb	
1A3*	1.4	0.15	0.5	330 volts	Cathode
5U4G	5.0	3.0	225	1550	Full wave
5Y3GT	5.0	2.0	125	1400	Full wave
6AL5*	6.3	0.3	9	420	Twin diode
6H6, 6H6GT	6.3	0.3	8	420	Twin diode
6X5GT	6.3	0.6	70	1250	Full wave
25Z6GT	25.0	0.3	75	700	Full wave
559	6.3	0.75	30	100	"Light-house" diode

Cathode-Ray Indicator Tubes

6AF6G	6.3	0.15	Dual indicator
6E5	6.3	0.3	Single indicator with triode

* Type not available prior to the war.

must withstand, without losing parts alignment, a shock equivalent to from 15,000 to 20,000 g, and a centrifugal force generated by rotation at the rate of 475 revolutions per minute.

(69) "Proximity fuze," *Electronics*, vol. 18, pp. 110–111; November, 1945.

An analysis of electron paths and current densities for beam-power tubes with parallel-plane configurations, including mathematical computation and a description of the physical picture, was published. A new study of emission from oxide-coated cathodes and a new analysis of transit-time effects in high-frequency tubes appeared.

(70) G. B. Walker, "Space charge effects between a positive grid and anode of a beam tetrode," *Wireless Eng.*, vol. 23, pp. 157–169; April, 1945; pp. 212–222; May, 1945; pp. 276–281; June, 1945.
(71) S. Rodda, "Space charge and electron deflections in beam tetrode theory," *Electronic Eng.*, vol. 17, pp. 541–545; June, 1945; pp. 589–592; July, 1945; pp. 649–652; August, 1945.
(72) Robert L. Sproull, "An investigation of short-time emission from oxide-coated cathodes," *Phys. Rev.*, vol. 67, pp. 167–178; March, 1945.
(73) Arthur B. Bronwell, "Electron transit time in varying fields," PROC. I.R.E., vol. 33, pp. 712–716; October, 1945.

There appeared descriptions of several new types of tubes.

(74) G. T. Ford, "Midget tubes for high frequencies," *Bell Lab. Rec.*, vol. 22, pp. 605–608; November, 1944.
(75) R. M. Smith, "Orbital beam UHF tubes," *Electronics*, vol. 18, pp. 103–105; May, 1945.

There were several interesting papers giving analyses of tube and circuit performance.

(76) John W. Miles, "Junction analysis in vacuum-tube circuits," PROC. I.R.E., vol. 32, pp. 617–620; October, 1944.
(77) J. R. Pierce, "Reflex oscillators," PROC. I.R.E., vol. 33, pp. 112–118; February, 1945. (Discussion, E. U. Condon, A. E. Harrison, W. W. Hansen, J. R. Woodyard, J. R. Pierce, PROC. I.R.E., vol. 33, pp. 483–485; July, 1945.)
(78) L. C. Peterson and F. B. Llewellyn, "The performance and measurement of mixers in terms of linear-network theory," PROC. I.R.E., vol. 33, pp. 458–476; July, 1945.
(79) W. W. Hansen, "On maximum gain-band width product in amplifiers," *Jour. Appl. Phys.*, vol. 16, pp. 528–534; September, 1945.
(80) E. W. Herold, R. R. Bush, and W. R. Ferris, "Conversion loss of diode mixers having image-frequency impedance," PROC. I.R.E., vol. 33, pp. 603–609; September, 1945.
(81) Robert J. Meyer, "Open-grid tubes in low-level amplifiers," *Electronics*, vol. 17, pp. 126–128, 234; October, 1944.

Phototubes

Little material on phototubes has appeared in the published literature during the year 1945 which would indicate progress of a fundamental research nature. However, during the war two large-scale military applications of phototubes were developed. The first required the development of a very rugged tube for use in a photoelectric version of the proximity fuze. Although a large quantity of such fuzes was built the radio-operated proximity fuze was deemed superior from a tactical standpoint. The photoelectron multiplier found itself in a novel spot. Because of the extraordinary gains available, the random-shot noise in the photocathode current could be amplified to a usable level for modulation of radar countermeasure or "jamming" signals. Effective combination of electronic jamming with other methods reduced bomber losses to a considerable degree.

The photoelectron multiplier continued to receive attention as a competitor of the photographic plate for rapid spectrochemical analysis.

(82) G. H. Dieke and H. M. Crosswhite, "Direct intensity measurements of spectrum lines with photo multiplier tubes," *Jour. Opt. Soc. Amer.*, vol. 35, pp. 471–480; July, 1945.
(83) George A. Nahstoll and Ford R. Bryan, "Application of multiplier photo-tubes to the spectro-chemical analysis of magnesium alloy," *Jour. Opt. Soc. Amer.*, vol. 35, pp. 646–650; October, 1945.
(84) J. L. Saunderson, V. J. Caldecourt, and E. W. Peterson, "Photoelectric instrument for direct spectro-chemical analysis,"

Jour. Opt. Soc. Amer., vol. 35, pp. 681–697; November, 1945.

Gas Tubes

Studies of the wave-forms of load currents obtained from one- and two-tube gas-tube rectifier circuits were published in one series of papers.

(85) P. T. Chin, "Gaseous rectifier circuits," *Electronics*, vol. 18, pp. 138–143; April, 1945; pp. 132–137; May, 1945.
(86) P. T. Chin and G. E. Walter, "Transient response of controlled rectifier circuits," *Trans. A.I.E.E.* (*Elec. Eng.*, April, 1945), vol. 64, pp. 208–214; April, 1945.

Further uses for sealed metal ignitron tubes were described.

(87) M. M. Morack, "Design of sealed ignitron rectifiers for three-wire service," *Trans. A.I.E.E.* (*Elec. Eng.*, March, 1945), vol. 64, pp. 103–107; March, 1945.

Theoretical determinations were made and experimental data were obtained with respect to the magnitude of currents obtained on arc back of power rectifiers.

(88) R. D. Evans and A. J. Maslin, "Arc-backs in rectifier circuits—artificial arc-back tests," *Trans. A.I.E.E.* (*Elec. Eng.*, June, 1945), vol. 64, pp. 303–311; June, 1945.
(89) C. C. Herskind and H. L. Kellogg, "Rectifier fault currents," *Trans. A.I.E.E.* (*Elec. Eng.*, March, 1945), vol. 64, pp. 145–150; March, 1945.

A description of latest ignitron design for high-voltage (15 kilovolts) operation was published.

(90) H. C. Steiner, J. L. Zehner, and H. E. Zuvers, "Pentode ignitrons for electronic power converters," *Trans. A.I.E.E.* (*Elec. Eng.*, October, 1944), vol. 63, pp. 693–697; October, 1944.

One paper discussed the interference caused by rectifier circuits.

(91) D. J. McDonald, "Rectifiers and inductive co-ordination," *Elec. Eng.*, vol. 64, pp. 60–64; February, 1945.

A description was given of a mass spectrometer tube and associated circuits.

(92) John A. Hipple, Don J. Grove, and W. M. Hickam, "Electronics of the mass spectrometer," *Elec. Eng.*, vol. 64, pp. 141–145; April, 1945.

A discussion of the economics involved in power-inversion circuits was given in one paper.

(93) S. B. Crary and R. M. Easley, "Frequency changers—characteristics, applications, and economics," *Trans. A.I.E.E.* (*Elec. Eng.*, June, 1945), vol. 64, pp. 351–358; June, 1945.

Cathode-Ray Tubes and Television Tubes

During the early part of 1945, cathode-ray and pickup tube development was continued for the war program. A few new cathode-ray tube types were introduced; one with nonglare coating, higher light output, and improved deflection sensitivity to be used in airborne equipment in high ambient light; one high-voltage, high-frequency type for the study of fast transient and high-frequency phenomena in the range of 10 to 100 megacycles.

(94) P. S. Christaldi, "Cathode-ray tubes and their applications," PROC. I.R.E., vol. 33, pp. 373–381; June, 1945.

Other types of cathode-ray tubes were developed with minor changes for special applications. A new pickup tube known as the image orthicon with high infrared sensitivity having an operating sensitivity of the order of 100 times that of the iconoscope, was made in production for the armed forces.

(95) "Sensitive television camera tubes," *Electronics*, vol. 18, p. 330; December, 1945.

The work on improved performance of the JAN preferred types of cathode-ray tubes was continued with the production of the so-called "zero first-anode current gun," having improved focus and decreased deflection defocusing, in practically all of the electrostatic-deflection types.

(96) L. E. Swedlund, "Improved electron gun for cathode-ray tubes," *Electronics*, vol. 18, pp. 122–124; March, 1945.

The resolution performance of the JAN magnetic-deflection types was greatly improved by the use of the so-called "limiting-aperture magnetic-focus gun."

In the United States the Joint Electron Tube Engineering Council (JETEC) Cathode-Ray Tube Committee was formed by combining the activities of The Radio Manufacturers Association (RMA) and The National Electrical Manufacturers Association (NEMA) for continuing activity in industry co-ordination of standardization of test methods and recommendation for cathode-ray-tube specifications.

Among the developments in cathode-ray tubes during the past four to five years for the war program, which can now be described, are the P7 and P14 double-layer long-persistence fluorescent screens, and the radio-deflection-type cathode-ray tube. The P7 and P14 are similar double-layer long-persistence screens. The P7 screen was developed early in the war program and was used in a number of radar cathode-ray-tube types manufactured in large quantities and used extensively in many types of radar equipment. The radial deflection type cathode-ray tube was developed to provide a longer base line and thereby improve the accuracy of small cathode-ray tubes which were used to a considerable extent in altimeter and gun-fire control equipment. The detailed performance characteristics of these tubes and the part they played in many equipments used during the war will undoubtedly appear in papers in the near future.

A number of important papers appeared on electron optics and beam focusing.

(97) G. Liebmann, "The image formation in cathode-ray tubes and the relation of fluorescent spot size and final anode voltage," PROC. I.R.E., vol. 33, pp. 381–389; June, 1945.
(98) J. R. Pierce, "A figure of merit for electron-concentrating systems," PROC. I.R.E., vol. 33, pp. 476–478; July, 1945.
(99) D. Gabor, "Dynamics of electron beams, application of Hamiltonian dynamics to electronic problems," PROC. I.R.E., vol. 33, pp. 792–805; November, 1945.
(100) C. J. Calbick, "Historical background of electron optics," *Jour. Appl. Phys.*, vol. 15, pp. 685–690; October, 1944.
(101) H. Gunther Rudenberg, "Deflection sensitivity of parallel-wire lines in cathode-ray oscillographs," *Jour. Appl. Phys.*, vol. 16, pp. 279–285; May, 1945.
(102) R. G. E. Hutter, "The class of electron lenses which satisfy Newton's image relations," *Jour. Appl. Phys.*, vol. 16, pp. 670–678; November, 1945.
(103) R. G. E. Hutter, "Rigorous treatment of the electrostatic immersion lens whose axial potential distribution is given by: $\phi(z)=\phi_0 e^{k \arctan z}$," *Jour. Appl. Phys.*, vol. 16, pp. 678–699; November, 1945.

(104) L. S. Goddard, "The computation of electron trajectories in axially symmetric fields," *Proc. Phys. Soc.* (London), vol. 56, pp. 372–378; November, 1944.
(105) L. S. Goddard and O. Klemperer, "Electron ray tracing through magnetic lenses," *Proc. Phys. Soc.* (London), vol. 56, pp. 378–396; November, 1944.
(106) A. L. Samuel, "Some notes on the design of electron guns," PROC. I.R.E., vol. 33, pp. 233–240; April, 1945.
(107) Otto Ackerman and Edward Beck, "Electronic oscillograph-time microscope," *Westinghouse Eng.*, vol. 4, pp. 169–173; November, 1944.

The field of electron microscopy continued to expand at a rapid rate with the development of new instruments and extension of applications to microchemical analysis and electron-diffraction studies of surface structure.

(108) Eileen I. Alessandrini, "The use of the electron diffraction camera to detect insulating films," *Jour. Appl. Phys.*, vol. 16, pp. 94–96; February, 1945.
(109) R. D. Heidenreich and L. Sturkey, "Crystal interference phenomena in electron microscope images," *Jour. Appl. Phys.*, vol. 16, pp. 97–105; February, 1945.
(110) D. G. Brubaker and M. L. Fuller, "The electrical charging of electron diffraction specimens," *Jour. Appl. Phys.*, vol. 16, pp. 128–130; March, 1945.
(111) L. Marton, "A 100-kv electron microscope," *Jour. Appl. Phys.*, vol. 16, pp. 131–138; March, 1945.
(112) "Abstracts of proceedings of the Electron Microscope Society of America meeting, November 16, 17, and 18, 1944, in Chicago, Illinois," *Jour. Appl. Phys.*, vol. 16, pp. 263–266; April, 1945.
(113) H. C. O'Brien, Jr., "Pigment dispersion methods for electron microscopy," *Jour. Appl. Phys.*, vol. 16, pp. 370–372; June, 1945.
(114) C. Marton, "A bibliography of electron microscopy III," *Jour. Appl. Phys.*, vol. 16, pp. 373–378; July, 1945.
(115) James Hillier and R. F. Baker, "A discussion of the illuminating system of the electron microscope," *Jour. Appl. Phys.*, vol. 16, pp. 469–483, August, 1945.
(116) E. A. Gulbransen, "An electron diffraction camera for the study of high temperature surface reactions," *Jour. Appl. Phys.*, vol. 16, pp. 718–724; November, 1945.
(117) R. B. Barnes, C. J. Burton, and R. G. Scott, "Electron microscopical replica techniques for the study of organic surfaces," *Jour. Phys.*, vol. 16, pp. 730–739; November, 1945.

During the latter half of the year, development work on cathode-ray and pickup tubes was largely directed toward the provision of improved tubes for postwar television. An effort was being made to utilize knowledge and experience gained during the war. The new cathode-ray tubes are expected to feature wide-angle deflection, shorter over-all length, essentially flat screen, higher picture brightness, and better resolution. The new pickup tubes are expected to have much higher sensitivity, smaller photocathode, making possible their use with a wider variety of lenses and with greater depth of focus. Detailed publications will doubtless appear in 1946 covering the new features of these new tubes.

Television

There was a very great increase in television activity in 1945 coincident with the end of the war. American industry proceeded with developments and plans aimed at the widespread use of television in the very near future. Most of the technical advances achieved in the course of this activity, however, have not yet been made public, so that there is little to report in this annual review.

During the year the basic technical standards for the transmission of television signals in 6-megacycle channels were finally developed by Panel 6 of the Radio Technical Planning Board in the United States and were adopted with slight changes for commercial broadcasting by the Federal Communications Commission.

(118) For reference to the work of the Radio Technical Planning Board, see PROC. I.R.E., vol. 33, p. 143; March, 1945.

In addition, some type tests and performance standards for transmitters were approved and work is continuing in this field. The Commission allocated thirteen 6-megacycle channels for use for commercial broadcasting between 44 megacycles and 216 megacycles, and a master geographical allocation plan providing for stations in practically all metropolitan areas was released. The Federal Communications Commission also allocated the band from 480 to 920 megacycles for experimental television operation, and the band from 1245 to 1325 megacycles for television-relay use.

During the year, most of the television stations already in operation increased their program time on the air but were still operating a limited program service. At the close of the year, however, every indication pointed to a large increase in the number of active stations during the coming year, and to an expanded broadcast program by all stations.

A new television radio-relay link from Washington to Philadelphia was completed during the year, and other previously built cable and radio-relay links between Philadelphia and New York, and between New York and Schenectady continued in operation. It is also worthy of note that a 2000-megacycle radio-relay link between studio and transmitter was in operation. This used a transmitting tube of the disk-seal type.

A new television camera tube, the "image orthicon," was announced and demonstrated. This tube gives an increase in sensitivity of up to 100 times over previously available tubes and therefore greatly widens the scope of television program operation.

The year also saw a marked increase in research and development in color television. While this fact has appeared in the public press, the results of these investigations have not yet appeared in technical publications.

A new discriminator circuit for the sound channel, which uses a frequency-modulated signal according to present standards, has been described. This is called a "ratio-detector." It does not require preceding limiter stages to obtain the interference- and noise-reduction properties which are characteristic of frequency-modulation reception.

During the year, a high-impedance (about 300 ohms) flexible transmission line of the solid-dielectric type was developed for use between a television receiving antenna and the receiver. This is a low-loss line for wide-band reception with a dipole or similar antenna. The line consists of a flat strip of low-loss dielectric, with conductors imbedded near the edges of the strip.

There has also been some work reported on the development of television amplifiers and other equipment

having television applications as indicated by some of the following references.

(119) H. E. Kallmann, R. E. Spencer, and C. P. Singer, "Transient response," PROC. I.R.E., vol. 33, pp. 169–195; March, 1945.
(120) G. Liebmann, "The image formation in cathode-ray tubes and the relation of fluorescent spot size and final anode voltage," PROC. I.R.E., vol. 33, pp. 381–389; June, 1945.
(121) M. J. Larsen, "Low-frequency compensation of video-frequency amplifiers," PROC. I.R.E., vol. 33, pp. 666–670; October, 1945.
(122) G. C. Sziklai and A. C. Schroeder, "Cathode-coupled wide-band amplifiers," PROC. I.R.E., vol. 33, pp. 701–709; October, 1945.
(123) G. C. Sziklai and A. C. Schroeder, "Band-pass bridged-T network for television intermediate-frequency amplifiers," PROC. I.R.E., vol. 33, pp. 709–711; October, 1945.
(124) W. R. Piggott, "Producing rectangular R-F pulses of known amplitude," *Wireless Eng.*, vol. 22, pp. 119–125; March, 1945.
(125) C. C. Eaglesfield, "A square-wave analyser," *Wireless Eng.*, vol. 22, pp. 223–232; May, 1945.
(126) H. Moss, "Time-base converter and frequency divider," *Wireless Eng.*, vol. 22, pp. 368–372; August, 1945.
(127) P. Nagy and M. J. Goddard, "Oscillograph for the direct measurement of frequency employing a signal converter," *Wireless Eng.*, vol. 22, pp. 429–441; September, 1945; pp. 489–496; October, 1945.
(128) R. G. Mitchell, "Cascade H. T. generator," *Wireless Eng.*, vol. 22, pp. 474–483; October, 1945.
(129) L. C. Jesty, "Scanning systems for colour television," *Electronic Eng.*, vol. 17, pp. 456–460; April, 1945.
(130) V. M. Bradley, "Engineering aspects of television programming," *Electronics*, vol. 18, pp. 107–109; March, 1945.
(131) J. H. Jupe, "Large screen television," abstract, *Electronics*, vol. 18, pp. 270, 274, 278; April, 1945.
(132) Emanuel Last, "Restorer-circuit operation," *Electronics*, vol. 18, pp. 132–133; September, 1945.
(133) F. J. Bingley, "VHF multiple-relay television network," *Electronics*, vol. 18, pp. 102–108; October, 1945.
(134) R. B. Austrian, "Some economic aspects of theater television," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 377–385; May, 1945.
(134) H. S. Osborne, "Coaxial cables and television transmission," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 403–418; June, 1945.
(135) D. W. Epstein and I. G. Maloff, "Projection television," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 443–455; June, 1945.
(136) A. H. Rosenthal, "Problems of theater television projection equipment," *Jour. Soc. Mot. Pic. Eng.*, vol. 45, pp. 218–240; September, 1945. Abstract, *Electronics*, vol. 18, pp. 218, 222, 226, 230; May, 1945.
(137) C. H. Bachman, "Image contrast in television," *Gen. Elec. Rev.*, vol. 48, pp. 13–19; September, 1945.
(138) E. A. Henry, "Practical design of video amplifiers," *QST*, vol. 29, pp. 11–16; April, 1945; *QST*, vol. 29, pp. 32–38; May, 1945.
(139) H. N. Kozanowski, "DC picture transfer," *Broadcast News*, pp. 32–34, 40; August, 1944, *Electronic Industries*, vol. 4, pp. 106–107, 140, 142, 144; April, 1945.
(140) K. Pestrecov, "Television optics," *Electronic Indus.*, vol. 4, pp. 80–82, 146, 150; August, 1945.
(141) S. W. Seeley, "Ratio detectors for frequency-modulation receivers," presented, New York Section, October 3, 1945, New York, N. Y.

Facsimile

During the year there have been technical developments both in the design of terminal equipment and in methods of facsimile transmission over radio circuits and wire lines. Terminal equipment for long-distance radio circuits has continued to run at approximately 100 revolutions per minute drum speed, and wire-line-message transmitting equipment at maximum speeds between 200 and 300 revolutions per minute. In the laboratories scanners and recorders for very much higher speeds have been built, some running at 1200 revolutions per minute or 80 square inches per minute. These developments represent progress in mechanisms, signal-frequency amplifiers, and synchronizing devices. Scanners and recorders with large drums are being regularly used for the transmission of weather maps. Special transceivers have been developed for high definition which scan at either 200 or 300 lines per inch. In signal amplifiers for fine detail and high speed, there has been an increasing use of electron-multiplier phototubes. Facsimile recording techniques and recording papers have found many war uses in apparatus quite outside the field of facsimile.

For long radio circuits, frequency-shift modulation, with one radio frequency for black and a slightly different one for white, has become well established and has brought considerable improvement in the quality of recorded pictures. Better operation is also observed over wire lines where simplification of scanners, recorders, and associated switching equipment have made the services function more smoothly and more reliably. Most wire-line transmissions continue to use an amplitude-modulated subcarrier, although subcarrier frequency modulation is under consideration. Experimental transmissions have also been made over microwave relay circuits and an early extension of these facilities is anticipated.

An ever-increasing volume of wire-line telegraph traffic is being sent by facsimile. In the United States over a million and a half messages were handled in 1945 by this method, and with the increased construction of equipment permitted by the relaxation of priority restrictions, this message volume should further increase. Visitors to this country show marked interest in facsimile as a practical method of record communication for the rehabilitation of communications services in some other countries. Its value in direct transmission of languages unsuited to teleprinter keyboards is now widely recognized.

With war production finished, active attention is being directed to other facsimile applications. There has been experimental operation in the field of railroad dispatching. Police departments have recommended its use as a part of their communication system. Studies and developments on broadcast facsimile have begun in several laboratories with the objective of designing apparatus suitable for receiving facsimile news in the home or office.

During the war years, over 1000 facsimile sets have been manufactured for the Army, Navy, and Office of War Information of the United States. These have provided the equipment for a world-wide development of picture transmission by these services. Secrecy restrictions have prevented a report on this activity until now, and it therefore seems worthwhile to include here the following paragraphs taken from an historical report of the United States Signal Corps. They describe the most extensive application of facsimile communication so far made.

"In December, 1941, the necessity of providing telephoto service for wartime operations was realized by the Signal Corps and direct responsibility for it was assigned to Army Communications Service. Newspicture equipment was adapted and tests were successfully conducted. In June, 1942, the first installation of the telephoto network for the exclusive transmission of military material to the various Defense Commands was made.

"Initially, telephoto equipment was installed at New Orleans and at New York City. The net control station was located in Washington. For more than a year the traffic, entirely continental, consisted of a daily submarine-situation map, transmitted to coastal points for G-2 to utilize in combatting the German underwater menace, and of semiweekly weather charts for the Army Air Forces. . . .

"Introduction of new and improved equipment and practices stimulated by the effective application of telephoto to military purposes resulted in an expansion of the network to include transmitting and receiving stations at San Antonio, Seattle, Pasadena, Memphis, and other domestic points. These provided the War Department with a contact at each of the Defense Commands, and with the headquarters of the Alaska Communications System. The service during its first year proved a great success.

"In January, 1943, at the request of the Air Corps, a station was installed at the California Institute of Technology, where the Meteorological Research Division of the Air Forces was then located. From this station weather charts and maps were transmitted for delivery to the Directorate of Weather. . . .

"At the beginning of 1943, the equipment necessary to adapt the wire telephoto to radio operation had been designed and manufactured. This resulted in an expansion of the War Department facsimile network overseas with the installation of a radiophoto station in Algiers in February, 1943. A specially selected team flew to Africa to get test equipment set up and to experiment with the types of photograph developing and printing best suited to transmission by radio. . . . The first Signal Corps radiophoto newspicture transmitted for release was taken on 18 March, 1943. It pictured a gun crew on the alert in North Africa. . . .

"In keeping with the War Department policy of informing the public as quickly as possible on the progress of the war, news combat photographs were radioed to Washington for immediate release to the press. The radiophoto network expanded rapidly. Stations were fast established at such cities as Caserta (Italy), London, Paris, Honolulu, Brisbane, Manila, and Berlin. Thousands of pictures have been transmitted from all theaters of operation and have been released in this country at approximately the same time their corresponding news stories hit front pages. Shots of the invasion of France, for example, were received in Washington within two hours after General Eisenhower's first communique was released.

"The radiophoto headquarters in the War Department's Signal Center was not always on the receiving end of pictures from the combat fronts. Throughout the war many transmissions were made from there for reproduction overseas in publications such as 'Stars and Stripes' and 'Yank.' The material transmitted consisted mostly of photographs of sporting events, happenings of national import, and items involving troops. . . .

"Vast improvements in the quality of photographs transmitted by radio have been accomplished by ACS. At first the single-sideband (voice) radio system was used exclusively for the transmission of pictures. Later, ACS co-ordinated the development of the carrier shift method of transmission by which photographs could be sent over continuous-wave circuits used normally for radioteletypewriter. By this method the radio carrier is radiated continuously at constant amplitude and its frequency is varied in direct proportion with the change in picture tone. The highest carrier frequency corresponds to picture black and the lowest to picture white. . . . The carrier shift method reduced the effects of fading and made possible an expansion of radiophoto activities to installations where voice facilities were unavailable. Through the constant experimentation of ACS, facsimile transmission has been so improved that it is often difficult to distinguish between radiophotos and originals. . . .

"The first news color picture ever transmitted by radio was released for publication on 3 August, 1945, though test for color separation prints began on 22 July. The photograph pictured the 'Big Three' at the Potsdam Conference. It was radioed from Berlin, where a radiophoto station was specially activated, to Washington where it was released to the news services. The time required for its transmission was approximately 21 minutes, the normal transmitting time being seven minutes per negative.

"Details for making and transmitting color photographs by radio were perfected jointly by ACS and APS. The historic first picture was taken with a one-shot camera which exposed three negatives simultaneously. From these exposures, three prints were made and each placed on a cylinder representing one of the three basic colors—red, yellow, and blue. The three prints were transmitted separately and combined into a color picture at the receiving terminal in Washington. Work is being continued by the Signal Corps to perfect radio color transmission and make it a regularly available service."

The following digest from the Signal Corps report lists the stations in operation and gives the number of pictures sent or received by each one during the year July 1, 1944 to June 30, 1945:

Stations	*Total Sent or Received*
Anchorage	775
Berlin	
Fairbanks	318
France (Mobile)	138
France (7th Army)	38
Honolulu	1100
India	142
Italy	1458
Leyte	36
London	5843
Manila	475
New York	9
Paris	2080
Saipan	185
San Francisco	230
France (6th Army Group)	6
S. W. Pacific Area (New Guinea)	336
Brisbane	457
Algiers	2
Total Year Ended June 30, 1945	13,608

(142) R. C. Davies and P. Lesser, "Facsimile equipment communication units," *Electronic Indus.*, vol. 4, pp. 96–99, 170; February, 1945.

(143) "Facsimile transmitter and receiver," *Radio News*, vol. 33, pp. 43, 110, 112; March, 1945.

Antennas

In spite of the war, the published record for the year discloses valuable material in the antenna field, though naturally many new aspects of the art are scarcely represented. For the purpose of this review, the following illustrations are given of literature in this field.

That the designer of radio equipment is well aware of problems involved in airplane design is evident in such papers as

(144) F. D. Bennett, P. D. Coleman, and A. S. Meier, "The design of broad-band aircraft-antenna systems," PROC. I.R.E., vol. 33, pp. 671–700; October, 1945.

(145) Charles B. Bovill, "Aerials for use on aircraft: A comparison between fixed and trailing types on the 900-meter waveband," *Jour. I.E.E.* (London), vol. 92, part III, pp. 105–119; June, 1945.

The first of these gives, in considerable detail, some of the techniques used at Aircraft Radio Laboratories, Wright Field. Measurement of antenna impedance, design of impedance-matching circuits, and the development of one type of broadband antenna for use on aircraft, are covered. The second analyzes antennas used in the medium-frequency range and compares the trailing and fixed types.

An analysis and defense of that system of direction finding which, in addition to a loop, employs a horizontal antenna to provide a voltage with which to neutralize the undesired pickup from the horizontal members of the loop, will be found in

(146) Frederick Emmons Terman and Joseph M. Pettit, "The compensated-loop direction finder," PROC. I.R.E., vol. 33, pp. 307–318; May, 1945.

Another paper proposed a system of automatic direction finding based on the use of a goniometer in which the radio pickups from cross-loops are in effect, converted into proportional direct currents which reverse in sense when a directional change causes the loop pick-up to pass through a null, thus imparting an unambiguous direction to a magnetic needle.

(147) C. C. Pine, "A new type of automatic radio direction finder," PROC. I.R.E., vol. 33, pp. 522–527; August, 1945.

A paper on the radio-instrument landing system adopted by the Civil Aeronautics Administration for use in this country by civil aviation gave technical details of the runway localizer which operates between 108 and 111 megacycles. The installation program, though already started, was not expected to attain full volume until after the war.

(148) Peter Caporale, "The CAA instrument landing system," *Electronics*, vol. 18, pp. 116–124; February, 1945; pp. 128–135; March, 1945.

A receiving antenna for use with the localizer was described.

(149) Bruce E. Montgomery, "A very-high-frequency aircraft antenna for the reception of 109-megacycle localizer signals," PROC. I.R.E., vol. 33, pp. 767–772; November, 1945.

The disclosure of new forms of antenna for frequency-modulation broadcasting and discussions of the relative advantage of different types have appeared, as illustrated by the following papers:

(150) M. W. Scheldorf, "Circular antennas for FM broadcasting," *FM Television*, vol. 5, pp. 30–34; May, 1945; pp. 39–42, 83; June, 1945.
(151) J. P. Taylor, "A square-loop FM antenna," *Electronics*, vol. 18, pp. 96–100; March, 1945.
(152) G. H. Brown and J. Epstein, "A pretuned turnstile antenna," *Electronics*, vol. 18, pp. 102–107; June, 1945.

The experimental and the theoretical approaches to a problem are illustrated by the following papers which, though not directly connected, will be found of special interest from this point of view:

(153) S. A. Schelkunoff, "Concerning Hallen's integral equation for cylindrical antennas," PROC. I.R.E., vol. 33, pp. 872–878; December, 1945.
(154) George H. Brown and O. M. Woodward, Jr., "Experimentally determined impedance characteristics of cylindrical antennas," PROC. I.R.E., vol. 33, pp. 257–262; April, 1945.

The performance of directional arrays has been studied experimentally and compared with theory.

(155) H. Page, "The measured performance of horizontal dipole transmitting arrays," *Jour. I.E.E.* (London), vol. 92, part III, pp. 68–70; June, 1945.

The directional properties of two intersecting planes as a "reflector" for an exciter located on the bisector are analyzed by

(156) E. B. Moullin, "Theory and performance of corner reflectors for aerials," *Jour. I.E.E.* (London), vol. 92, part III, pp. 58–67; June, 1945.

In the following:

(157) J. Cooper and E. Green, "The design of directional aerial arrays," *Marconi Rev.*, vol. 8, pp. 12–23; January-March, 1945.

is given an example of the design of arrays to give a predetermined directional characteristic.

Among other titles indicative of the range of antenna interest during 1945 are the following:

(158) M. W. Scheldorf, "A new studio-to-transmitter antenna," PROC. I.R.E., vol. 33, pp. 106–112; February, 1945.
(159) C. W. Hansell, "Radio-relay-systems development by the Radio Corporation of America," PROC. I.R.E., vol. 33, pp. 156–168; March, 1945
(160) Chandler Stewart, Jr., "A proposed standard dummy antenna for testing aircraft-radio transmitters," PROC. I.R.E., vol. 33, pp. 772–777; November, 1945.

Radio Wave Propagation

During the final year of the war, investigations of wave propagation were carried on extensively in the United States and other countries in connection with communication, radar, and navigation systems employed in military operations. Much of the information accumulated in the course of these studies will doubtless prove of great interest when it is eventually released for publication. Fortunately, the rapid rate at which declassification of military material is proceeding leads one to hope that the major part of it will be generally available before the end of another year.

Books

There was published in 1945 a somewhat larger number of volumes containing sections on wave propagation than appeared during the two preceding years.

(161) A. de Quervain, "Cavity Resonators and Their Application in Ultra-Short-Wave Amplifier Engineering," A. G. Gebr. Leeman and Co., Zurich, Switzerland, 1944.
(162) W. L. Emery, "Ultra-High-Frequency Radio Engineering," Macmillan Co., New York, N. Y., 1944.
(163) W. Jackson, "High Frequency Transmission Lines," Methuen and Co., London, England, 1945.
(164) R. W. P. King, "Electromagnetic Engineering," McGraw-Hill Book Co., Inc., New York, N. Y., 1945.
(165) R. W. P. King, H. R. Mimno, and A. H. Wing, "Transmission Lines, Antennas, and Wave Guides," McGraw-Hill Book Co., Inc., New York, N. Y., 1945.
(166) M. S. Kiver, "UHF Radio Simplified," D. Van Nostrand Co., Inc., New York, N. Y., 1945.
(167) S. Ramo, "Introduction to Microwaves," McGraw-Hill Book Co., Inc., New York, N. Y., 1945.
(168) Standards on Radio Wave Propagation: "Definition of Terms Relating to Guided Waves," The Institute of Radio Engineers, New York, N. Y., 1942.

Ionosphere

Even fewer papers dealing with the ionosphere have been published in 1945 than in 1944. In 1945 the USSR and the United States have each contributed about a fourth of the year's papers, while England and India each provided an eighth. The remaining quarter have come from France, Sweden, and China. The theory of reflection and cosmic relations has received continued attention, as has the constitution of the upper atmosphere, diffusion, and absorption. Work has been reported on each of the D, E, and F layers and on fade-outs and solar-eclipse observations. There have been few contributions to the communication problems, presumably because of military regulations.

(169) J. Alpert and V. Ginsburg, "Absorption of radio waves in the ionosphere," *Bull. de l'Acad. des Sci. de l'URSS (Izvestiya), Série Physique*, vol. 8, pp. 42–67; 1944. (In Russian.) *Jour. Phys.* (U.S.S.R.) vol. 8, p. 383; 1944. (Summary in English.)
(170) J. Alpert and B. Gorozhankin, "Solar eclipses and radio investigations of the ionosphere," *Bull. de l'Acad. des Sci. de*

l'URSS (*Izvestiya*), *Série Physique*, vol. 8, pp. 85–108; 1944. (In Russian.) *Jour. Phys.* (U.S.S.R.), vol. 8, p. 382; 1944. (Summary, in English.)
(171) S. S. Baral and S. N. Mitra, "Effect of solar eclipse on the ionosphere," *Science and Culture* (Calcutta), vol. 10, pp. 175–176; October, 1944.
(172) A. C. Clarke, "V2 for ionosphere research," *Wireless World*, vol. 51, p. 58; February, 1945.
(173) T. G. Cowling, "The electrical conductivity of an ionized gas in a magnetic field, with applications to the solar atmosphere and the ionosphere," *Proc. Roy. Soc.*, ser. A, vol. 183, pp. 453–479; June, 1945.
(174) J. H. DeWitt, Jr. and A. D. Ring, "Significant radiation from directional antennas of broadcast stations for determining sky-wave interference at short distances," PROC. I.R.E., vol. 32, pp. 668–673; November, 1944.
(175) V. C. A. Ferraro, "Diffusion of ions in the ionosphere," *Terr. Mag. and Atmos. Elec.*, vol. 50, pp. 215–222; September, 1945.
(176) V. C. A. Ferraro, "On the electrical state of the upper atmosphere," *Terr. Mag. and Atmos. Elec.*, vol. 50, pp. 223–229; September, 1945.
(177) O. P. Ferrell, "Radio investigation of air movement in the upper atmosphere," *Science and Culture* (Calcutta), vol. 9, p. 555; June, 1944.
(178) Perry Fennell, Jr., "Winds in the ionosphere indicated by radio 'Clouds'," *Bull. Amer. Met. Soc.*, vol. 25, p. 371; November, 1944.
(179) J. A. Fleming, "Summary of the year's work to June 30, 1944, Department of Terrestrial Magnetism, Carnegie Institution of Washington," *Terr. Mag. and Atmos. Elec.*, vol. 49, pp. 245–250; December, 1944.
(180) V. Ginsburg, "The reflection of radio impulses from the ionosphere," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 7, pp. 114–133; 1943. (In Russian.)
(181) V. Ginsburg, "The refraction index of an ionized gas (ionosphere)," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, 1944. *Jour. Phys.* (U.S.S.R.), vol. 8, p. 383, 1944. (Summary in English.)
(182) M. N. Gnevyshev, "On certain problems in the physics of the ionosphere and geomagnetic disturbances, and on the equivalent problems in astrophysics," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 7, pp. 134–144; 1943. (In Russian.)
(183) M. M. Sengupta and S. K. Dutt, "On the experimental investigation of night-time ion-densities and their determination by the application of Chapman's formula," *Indian Jour. Phys.*, vol. 18, pp. 88–96; April, 1944.
(184) H. E. Hallborg, "Sun, earth, and short-wave propagation: effects of the solar system upon long-distance short-wave communication," *Proc. Radio Club Amer.*, vol. 21, pp. 1–6; December, 1944.
(185) C. K. Jen, K. T. Chow, Y. T. Co, and C. C. Kuan, "An observation on the ionosphere during the solar eclipse of July 20, 1944," *Phys. Rev.*, vol. 66, p. 226; October, 1944.
(186) R. Jouaust, "The mechanism of fade-outs of radio electric waves," *Comptes Rendus* (Paris), vol. 216, pp. 294–295; March, 1943.
(187) V. N. Kessenikh, "An estimation of the integral absorption in the ionosphere according to measurements of the strength of vertical field," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 8, pp. 68–75; 1944.
(188) V. N. Kessenikh and H. D. Bulatov, "The continental effect in the geographic distribution of the electron concentration in the F_2 layer," *Comptes Rendus* (Doklady), *de l'Acad. des Sci. de l'URSS*, vol. 45, pp. 234–237; November, 1944. On December 28, 1945, the Slavonic Division of the New York Public Library reported that this volume was in the bindery.
(189) M. A. R. Khán, "Hissing sounds heard during the flight of fireballs," *Nature*, vol. 155, p. 53; January 13, 1945.
(190) D. F. Martyn, "Anamolous behavior of the F_2 region of the ionosphere," *Nature*, vol. 155, pp. 363–364; March 24, 1945.
(191) J. B. Moore, "Fading effects at high frequencies," *Electronics*, vol. 17, pp. 100–106; October, 1944.
(192) E. R. Mustel, "Connection between faculae and geomagnetic activity," *Comptes Rendus* (Doklady) *de l'Acad. des Sci. de l'URSS*, vol. 42, pp. 112–115; January, 1944.
(193) R. Rawer, "The formation of the abnormal E-layer of the ionosphere," *Naturwiss.*, vol. 28, p. 577; September, 1940.
(194) R. Rivault, "Study of the D region of the ionosphere," *Comptes Rendus* (Paris), vol. 216, pp. 494–496; April, 1943.
(195) O. E. H. Rydbeck, "On the Propagation of Radio Waves," Göteborg, Chalmers Tekniska Högskolas Handlingar, 168 pages, 1944.
(196) O. E. H. Rydbeck, "A Theoretical Survey of the Possibilities of Determining the Distribution of the Free Electrons in the Upper Atmosphere," Göteborg, Chalmers Tekniska Högskolas Handlingar, 74 pages, 1942.
(197) I. Tamm, "On currents in the ionosphere which cause the variations of the terrestrial magnetic field," *Jour. Phys.* (U.S.S.R.), vol. 8, p. 383; 1944. (Summary, in English.) Published in full, in Russian, in *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 8, pp. 30–41; 1944.
(198) A. Vassy and E. Vassy, "The temperature of the upper atmosphere," *Jour. de Phys. et le Radium*, vol. 3, p. 8; January, 1942.
(199) W. Waldmeier, "Ionospheric determination of the ultra violet intensities of the solar radiation in the region 700–900 A.U., *Helv. Phys. Acta*, vol. 17, pp. 168–180; 1944.
(200) "Solar eclipse observations: Effects on the ionization of the E and F layers," *Wireless World*, vol. 51, p. 240; August, 1945.
(201) Ta-You Wu, "Recombination processes in the E-layer of the ionosphere," *Terr. Mag. and Atmos. Elec.*, vol. 50, pp. 57–62; March, 1945.

Effect of the Troposphere and Earth on Propagation

A very large portion of the work on radio wave propagation done during the war under the restrictions of military security was related to propagation in a non-homogeneous atmosphere. These investigations will contribute greatly to a qualitative understanding of the effect of the troposphere on propagation but the practical utility of numerical calculations has been severely limited by the lack of necessary meteorological data. Relatively few papers on the subject of any great significance appeared in journals available to the general public. On the other hand, papers dealing with discontinuities or irregularities in the earth's surface are being published in increasing numbers. Two papers dealing with the effect of various soils on propagation are reported.

(202) J. Alpert and B. Gorozhankin, "Experimental investigation of the structure of an electromagnetic field over the inhomogeneous earth's surface," *Jour. Phys.* (U.S.S.R.), vol. 9, pp. 115–122; 1945.
(203) S. S. Banerjee, "Effect of water vapor in the atmosphere on the propagation of ultra-short radio waves," *Science and Culture* (Calcutta), vol. 10, pp. 453–454; April, 1945.
(204) P. Caporale, "The CAA instrument landing system," *Electronics*, vol. 18, pp. 128–135; March, 1945.
(205) L. DeBroglie, "On the propagation of luminous energy in anistropic media," *Comptes Rendus*, Paris, vol. 215, p. 153; August, 1942.
(206) E. Feinberg, "On the propagation of radio waves along an imperfect surface," *Jour. Phys.* (U.S.S.R.), vol. 8, pp. 317–330; 1944. (In English.)
(207) E. Feinberg, "The effective path of radio waves," *Jour. Phys.* (U.S.S.R.), vol. 8, p. 382; 1944. (In English, summary only.) In full, in Russian, in *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*; 1944.
(208) E. Feinberg, "On the propagation of radio waves along the real surface of the earth," *Jour. Phys.* (U.S.S.R.), vol. 8, p. 382. (In English, summary only.) In full, in Russian, in *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*; 1944.
(209) E. Feinberg, "On the propagation of radio waves along an imperfect surface," *Jour. Phys.* (U.S.S.R.), vol. 9, pp. 1–6; 1945.
(210) V. A. Fock, "The electrical field near a depression in a conducting plane," *Comptes Rendus* (Doklady) *de l'Acad des Sci. de l'URSS*, vol. 40, pp. 343–345; September, 1943. (In English.)
(211) Albert W. Friend, "A summary and interpretation of ultra-short-wave-propagation collected by the late Ross A. Hull," PROC. I.R.E., vol. 33, pp. 358–373; June, 1945.
(212) W. Geffcken, "Reflexion of electromagnetic waves at an inhomogeneous layer," (in German), Ann. der Phys., vol. 40, pp. 385–492; 1941.
(213) V. L. Ginsburg, "On the paramagnetic effects influencing the radio wave propagation in the atmosphere," *Comptes Rendus* (Doklady) *de l'Acad. des Sci. de l'URSS*, vol. 35, pp. 270–273; June, 1942. (In English.)
(214) V. L. Ginsburg, "On the effect of polar and paramagnetic molecules on the absorption and refraction of radio waves in the atmosphere," *Bull. de l'Acad. des Sci. de l'URSS, Série Physique* (*Izvestiya*), vol. 7, pp. 96–98; 1943. (In Russian.)
(215) R. Guelke, "A geophysical prospecting instrument using

alternating currents of audio frequency," *Jour. Sci. Instr.*, vol. 22, pp. 141–145; August, 1945.
(216) G. A. Grünberg, "On the propagation of radio waves over the surface of the earth, taking into account the non-uniformity of the atmosphere and the shape of the earth," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 7, pp. 99–113; 1943. (In Russian.)
(217) G. W. O. Howe, "The radiation resistance of a half-wave dipole aerial," *Wireless Eng.*, vol. 22, pp. 153–156; April, 1945.
(218) N. N. Kalitin, "On scattering of radiation by clouds," *Comptes Rendus* (Doklady) *de l'Acad. des Sci. de l'URSS*, vol. 43, pp. 289–291; June, 1944. (In English.)
(219) D. I. Lawson, "Multipath interference in television transmission," *Jour. I.E.E.* (London), vol. 92, part III, pp. 125–144; September, 1945.
(220) M. Leontovich, "Concerning a certain method for solving problems of propagation of electromagnetic waves along the earth's surface," *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), *Série Physique*, vol. 8, pp. 16–22; 1944. *Jour. Phys.* (U.S.S.R.), vol. 8, p. 382; 1944. (In English, summary only.)
(221) C. Mihul, "Reflection of electromagnetic waves by media whose optical constants vary in a continuous fashion," *Phys. Berichte*, vol. 24, p. 1323; 1943. Summary of a paper which appears in a publication from Jassy University. Translation of part of summary in *Wireless Eng.*, vol. 22, pp. 444–445; September, 1945.
(222) F. Odone, "Propagation, according to geometrical optics, of a monochromatic luminous wave in an isotropic heterogeneous medium," *Nuovo Cimento* (Turin), vol. 19, p. 157; May/July, 1942. Abstract, *Wireless Eng.*, vol. 22, p. 444; September, 1945.
(223) Ralph G. Peters, "45.5 and 91-mc field intensity tests," *Communications*, vol. 25, pp. 68, 70, 72; April, 1945.
(224) L. Pincherle, "The polarizing angle for reflection at the boundary between two absorbing media," *Proc. Phys. Soc.*, vol. 57, part 1, pp. 56–60; January 1, 1945.
(225) B. Polic, "The investigation of the propagation of electromagnetic waves in mountain and river valleys, fiords, etc., by means of models," *Telegraphen-Fernsprech- und Funk-Technik*, vol. 33, pp. 63–78; April, 1944.
(226) S. N. F. Rahman and F. Muhi, "Electrical properties of Indian soils at medium broadcast frequencies," *Indian Jour. Phys.*, vol. 18, pp. 31–37; February, 1944.
(227) T. W. Wigton, "Railroad radio communication on the V.H.F.'s," *Radio*, vol. 29, pp. 35–39; August, 1945.

Propagation Along Lines and in Guides

By far the most important advances in this domain made during the war have to do with wave guides. A vast amount of progress has been made in the development of techniques and engineering data for their use. This information is now largely declassified and shortly should be available to all. Published material during 1945 represents, on the whole, rather modest contributions to the art, with a preponderance of papers containing design data and charts.

Parallel-Wire Transmission Lines

There were no important theoretical contributions to general line theory in 1945. Some expository papers were published, and some suggestions for approximate or graphical methods of determining line constants. There was also more detailed discussion of the design of single- and double-stub matching sections.

(228) A. Bloch, "Fresnel's reflection formulae and parallel transmission lines," *Wireless Eng.*, vol. 21, pp. 560–562; December, 1944.
(229) B. C. Dees, "Graphical methods of solving transmission-line problems," *Radio News, Radio-Electronic Dept.*, vol. 5, pp. 16–18, 41–44; August, 1945; pp. 18–20, 24–26; September, 1945.
(230) Edward N. Dingley, Jr., "The theory of transmission lines," Proc. I.R.E., vol. 33, pp. 118–125; February, 1945; discussion, pp. 810–812; November, 1945.
(231) A. C. Gardner, "Parallel wire transmission lines," *Radio*, vol. 29, pp. 25–28, 60; April, 1945.
(232) T. A. Garretson, "Transmission lines at 200 mc.," *Radio News*, vol. 33, pp. 28–31, 90, 92–94; February, 1945.
(233) G. W. O. Howe, "Resonance in quarter-wave lines," *Wireless Eng.*, vol. 21, pp. 509–511; November, 1944.
(234) R. G. Middleton, "Graphical treatment of high frequency lines," *Radio News, Radio-Electronic Dept.*, vol. 3, pp. 20–22, 38–39; December, 1944.
(235) H. E. Newell, Jr., "Transmission lines as tuning elements," *Electronics*, vol. 18, pp. 150, 152; October, 1945.
(236) Robert C. Paine, "Graphical solution of voltage and current distribution and impedance of transmission lines," Proc. I.R.E., vol. 32, pp. 686–695; November, 1944.
(237) R. C. Paine, "Transmission-line impedance matching chart," *Radio*, vol. 29, pp. 34–36, 62, 64; February, 1945.
(238) R. C. Paine, "Transmission-line calculator," *Electronics*, vol. 18, pp. 140–141; March, 1945.
(239) R. C. Paine, "Graphical method for computing transmission-line impedance," *Radio News, Radio-Electronic Dept.*, vol. 4, pp. 10–12, 41–42; June, 1945.
(240) R. C. Paine, "Computing double-stub lengths for lines," *Electronic Indus.*, vol. 4, pp. 94–96, 194; July, 1945.
(241) R. C. Paine, "Solving transmission-line problems," *Communications*, vol. 25, pp. 66–67, 89; October, 1945.
(242) R. H. Paul, "Rigorous methods of solving long transmission-line problems," *Jour. I.E.E.* (London), vol. 92, part 2, pp. 20–22; February, 1945.
(243) D. H. Ray, "High-frequency transmission," *Jour. I.E.E.* (London), vol. 92, part 1, pp. 133–134; March, 1945.
(244) A. C. Schwager and P. Y. Wang, "New transmission-line diagrams," *Trans. A.I.E.E.* (*Elec. Eng.*, September, 1945), vol. 64, pp. 610–615; September, 1945.
(245) R. Sibson, "Loss-free transmission lines," *Wireless Eng.*, vol. 22, pp. 420–428; September, 1945.
(246) T. F. Wall, "Alternating current transmission," *Engineering* (London), vol. 160, pp. 1–3; July 6, 1945; pp. 61–62; July 27, 1945; pp. 101–102; August 10, 1945; pp. 201–202, September 14, 1945.

Coaxial Transmission Lines

Emphasis in this field was chiefly in the technique of measurements at increasingly high frequencies. One paper on discontinuities in coaxial lines appeared, and the use of solid-dielectric cables in the ultra-high-frequency range was being carefully studied. The elimination of reflection in a line terminated by a thin film was discussed theoretically.

(247) P. R. Bray, "Approximate formulae for the calculation of attenuation from open and closed impedances," *Post Office Elec. Eng. Jour.*, vol. 38, pp. 52–55; July, 1945.
(248) G. W. O. Howe, "Resonance in quarter-wave lines," *Wireless Eng.*, vol. 21, pp. 509–511; November, 1944.
(249) F. Jones and R. Sear, "Testing high-frequency cables," *Wireless Eng.*, vol. 21, pp. 512–520; November, 1944; pp. 571–583; December, 1944.
(250) A. G. Kandoian, "Special transmission problems in solid dielectric high frequency cable," *Elec. Commun.*, vol. 22, pp. 198–202; 1945.
(251) N. D. Kenney, "Coaxial cable design," *Electronics*, vol. 18, pp. 124–128; May, 1945.
(252) N. Marchand, "Special aspects of high frequency flexible balanced cables," *Elec. Commun.*, vol. 22, pp. 193–197; 1945.
(253) N. Marchand and R. Chapman, "U-H-F impedance measurements," *Electronics*, vol. 18, pp. 97–101; June, 1945.
(254) D. H. Smith, "The non-reflecting termination of a transmission line," *Proc. Phys. Soc.* (London), vol. 57, pp. 90–96; March 1, 1945.
(255) Chandler Stewart, Jr., "A method of measuring attenuation of short lengths of coaxial cable," Proc. I.R.E., vol. 33, pp. 46–48; January, 1945.
(256) Chandler Stewart, Jr., "Electrical testing of coaxial radio-frequency cable connectors," Proc. I.R.E., vol. 33, pp. 609–619; September, 1945.
(257) Chandler Stewart, Jr., "The S-function method of measuring attenuation of coaxial radio-frequency cable," *Trans. A.I.E.E.* (*Elec. Eng.*, September, 1945), vol. 64, pp. 616–619; September, 1945.
(258) P. H. Ware, "Coaxial cable tests," *Electronics*, vol. 18, pp. 130–134; October, 1945.
(259) A. J. Warner, "Dielectrics in U-H-F flexible coaxial cables," *Communications*, vol. 24, pp. 33–35, 54, 90–91; December, 1944.
(260) J. R. Whinnery, H. W. Jamieson, and Theo Eloise Robbins, "Coaxial-line discontinuities," Proc. I.R.E., vol. 32, pp. 695–709; November, 1944.

(261) W. H. Wood, "Approximate losses for various sizes of concentric transmission lines at 46 mc.," *Communications*, vol. 25, p. 64; March, 1945.

Cylindrical Wave Guides

The field of a rectangular wave guide due to a transverse current filament was given careful theoretical treatment. The application of the Lorentz transformation to the field in a rectangular wave guide, and a study of the field in the vicinity of a gap in a cylindrical conductor should also be noted.

(262) G. R. Cooper, "Circular wave guide fields," *Electronics*, vol. 18, pp. 106–109; February, 1945.
(263) W. D. Hershberger, "Waves guides and the special theory of relativity," *Jour. Appl. Phys.*, vol. 16, pp. 465–468; August, 1945.
(264) "Discussion on 'Wave guides in electrical communication,'" *Jour. I.E.E.* (London) vol. 91, part III, pp. 145–155; September, 1944.
(265) S. S. Mackeown and John W. Miles, "The plane-wave resolution of guided waves," Proc. I.R.E., vol. 33, pp. 805–808; November, 1945.
(266) E. B. Moullin, "The propagation of electric waves in a rectangular wave guide," *Jour. I.E.E.* (London), vol. 92, part III, pp. 8–17; March, 1945.
(267) S. A. Schelkunoff, "On waves in bent pipes," *Quart. Appl. Math.*, vol. 2, pp. 171–172; July, 1944.
(268) J. McG. Sowerby, "Radio data charts: attenuation in wave guides," *Wireless World*, vol. 50, pp. 328–331; November, 1944.
(269) E. M. Studenkov, "Propagation of electromagnetic waves in branched hollow-pipe lines," *Jour. Phys.* (U.S.S.R.), vol. 7, pp. 308–309; 1943.
(270) C. C. Wang, "Electromagnetic field inside a cylinder with a gap," *Jour. Appl. Phys.*, vol. 16, pp. 351–366; June, 1945.

Tapered Transmission Lines

One paper on tapered lines considered two kinds of taper, exponential and "lumped," for which fairly simple solutions of the transmission equations could be obtained.

(271) J. W. Milnor, "The tapered transmission line," *Trans. A.I.E.E.* (*Elec. Eng.*, June, 1945), vol. 64, pp. 345–346; June, 1945.
(272) D. H. Smith, "The non-reflecting termination of a transmission line," *Proc. Phys. Soc.* (London), vol. 57, pp. 90–96; March 1, 1945.

General Theory and Experiments

The number of papers published during the past year on more general aspects of wave propagation was relatively small, but several were of considerable interest. The paper by Bethe on diffraction is representative of a rather large amount of theoretical work done during the war in this country and in England on the coupling of wave guides and cavity resonators. The theory of scattering and noise from stellar space continue to be of interest.

(273) H. Alfvén, "On the existence of electromagnetic-hydrodynamic waves (in conducting liquids in a uniform magnetic field: importance in the formation of sunspots)," *Phys. Berichte*, vol. 25, p. 92; 1944.
(274) H. A. Bethe, "Theory of diffraction by small holes," *Phys. Rev.*, vol. 66, pp. 163–182; October, 1944.
(275) N. E. Dorsey, "The velocity of light," *Trans. Amer. Phil. Soc.*, vol. 34, pp. 1–110; October, 1944.
(276) H. Feshbach, "On the perturbation of boundary conditions," *Phys. Rev.*, vol. 65, pp. 307–318; June, 1944.
(277) L. L. Foldy, "The multiple scattering of waves: I. General theory of isotropic scattering by randomly distributed scatterers," *Phys. Rev.*, vol. 67, pp. 107–119; February 1 and 15, 1945.
(278) H. Fröhlich, "Theory of dielectric constant and energy loss in solids and liquids," *Jour. I.E.E.* (London), vol. 91, part I, pp. 456–463; December, 1944.
(279) H. Gutton and J. Ortusi, "A study of guided Hertzian waves: Application to the filtering of decimetric waves," *Bull. de la Soc. Franc. des Elec.*; February, 1944.
(280) H. Gutton and J. Ortusi, "On the theorem of reciprocity for Hertzian waves," *Comptes Rendus* (Paris), vol. 217, pp. 677–679; December, 1943.
(281) M. G. Scroggie, "Waves guides: how to visualise their action and characteristics: modes in circular guides: launching and collecting devices," *Wireless World*, vol. 50, pp. 258–261; September, 1944; pp. 303–307; October, 1944.
(282) G. C. Southworth, "Microwave radiation from the sun," *Jour. Frank. Inst.*, vol. 239, pp. 285–297; April, 1945.
(283) V. Vladimirsky, "Propagation of electromagnetic waves along a single wire," *Jour. Phys.* (U.S.S.R.), vol. 8, p. 382; 1944. (In English, summary only.) In full in *Bull. de l'Acad. des Sci. de l'URSS* (*Izvestiya*), vol. 8, 1944.
(284) "Measurement of V-H-F bursts," *Electronics*, vol. 18, p. 105; January, 1945.

Cavity Resonators

The number of papers dealing with cavity resonators continues to increase. This subject is one which borders also on circuit theory.

(285) J. Bernier, "Principle of equivalence between an electromagnetic cavity and a circuit with localized constants," *Comptes Rendus* (Paris), vol. 217, pp. 424–426; November, 1943.
(286) J. Bernier, "Principles for the calculation of electromagnetic cavities," *Comptes Rendus* (Paris), vol. 217, pp. 530–532; November, 1943.
(287) J. Bernier, "A reference method for the calculation of electromagnetic cavities," *Comptes Rendus* (Paris), vol. 218, pp. 186–188; January, 1944.
(288) F. Borgnis, "Resonance of electromagnetically excited cavities," *Zeit. für Phys.*, vol. 122, pp. 407–412; May, 1944.
(289) H. A. Brown, "Frequency of capacitance tuned lines and resonant line oscillators," *Communications*, vol. 25, pp. 51–52, 54, 56, 90–93; May, 1945.
(290) C. F. Davidson and J. C. Simmonds, "Cylindrical cavity resonators," *Wireless Eng.*, vol. 21, pp. 420–424; September, 1944.
(291) L. S. Goddard, "A method for computing the resonant wave length of a type of cavity resonator," *Cambridge Phil. Soc. Proc.*, vol. 41, pp. 160–175; August, 1945.
(292) M. S. Kiver, "Theory and application of U-H-F, part 9: Covering the principles and operation of commonly employed methods used to obtain energy from cavity resonators," *Radio News*, vol. 33, pp. 58–59, 150, 151; February, 1945.
(293) W. R. MacLean, "The reactance theorem for a resonator," Proc. I.R.E., vol. 33, pp. 539–541; August, 1945.
(294) D. Middleton and R. King, "Transmission-line theory applied to wave guides and cavity resonators," *Jour. Appl. Phys.*, vol. 15, pp. 524–535; July, 1944.
(295) D. Middleton, "Transmission-line theory applied to wave guides and cavity resonators," *Jour. Appl. Phys.*, vol. 15, pp. 535–544; July, 1944.
(296) R. Warnecke and J. Bernier, "Electronic generation of electromagnetic waves in a cavity resonator," *Comptes Rendus* (Paris), vol. 218, pp. 73–75; January, 1944.
(297) R. A. Whiteman, "Cavity resonators," *Radio News*, *Radio-Electronic Dept.*, vol. 5, pp. 11–13, 41–44; September, 1945.
(298) C. N. Works, T. W. Dakin, and F. W. Boggs, "A resonant-cavity method for measuring dielectric properties at ultra-high frequencies," Proc. I.R.E., vol. 33, pp. 245–254; April, 1945.

Piezoelectric Crystals

Among the references in this section are a few published prior to 1945, which were not yet at hand when the 1944 report was prepared.

Recent advances in piezoelectricity have had to do mainly with the study of certain artificially grown crystals and with the technique and performance of quartz plates for thickness vibrations.

The activities of the Zurich investigators, mentioned in the report for 1944, were continued. Although nothing particularly exciting came to light, considerable progress was made in the study of the dielectric, piezoelectric, optical, and thermal properties of the primary

phosphates and arsenates of potassium, ammonium, and deuterium. Some tests were also made of rubidium phosphate and of ammonium-phosphate crystals in which the ammonium was partly replaced with thallium. In particular, it was found that the face-shear vibrational modes of Z-cut plates cut from KH_2PO_4 and $NH_4H_2PO_4$ crystals have a zero temperature coefficient of frequency in the neighborhood of 0 degrees centrigrade, while for KD_2PO_4 the zero coefficient comes at 20 degrees centigrade. Observations on the converse piezoelectric effect in KH_2PO_4 led to the conclusion that in this crystal, as in Rochelle salt, the physical anomalies could be attributed to anomalies in the dielectric constant.

The piezoelectric constant d_{36} was measured for KH_2PO_4 and $NH_4H_2PO_4$ over a wide range of temperatures, by a dynamic method.

(299) A. von Arx and W. Bantle, "The converse piezo effect of the Seignette-electric crystal KH_2PO_4," *Helv. Phys. Acta*, vol. 17, pp. 298–318; 1944.
(300) W. Bantle, "An artificially grown crystal with a zero temperature-coefficient of resonant frequency at room temperature," *Helv. Phys. Acta*, vol. 18, pp. 245–247; 1945.
(301) W. Bantle and B. Matthias, "A purely electrical method for the measurement of piezoelectric constants," *Helv. Phys. Acta*, vol. 18, pp. 242–245; 1945.
(302) W. Bantle, B. Matthias, and P. Scherrer, "Dynamic measurements with KH_2PO_4 and $NH_4H_2PO_4$ crystals," *Helv. Phys. Acta*, vol. 18, pp. 389–404; 1945.
(303) P. Bärtschi, B. Matthias, W. Merz, and P. Scherrer, "Displacement of the transition point of the NH_4-rotation transformation," *Helv. Phys. Acta*, vol. 18, pp. 238–240; 1945.
(304) P. Bärtschi, B. Matthias, W. Merz, and P. Scherrer, "A new Seignette-electric modification of rubidium phosphate," *Helv. Phys. Acta*, vol. 18, pp. 240–242; 1945.
(305) B. Zwicker and P. Scherrer, "Electro-optical properties of the Seignette-electric crystals KH_2PO_4 and KD_2PO_4," *Helv. Phys. Acta*, vol. 17, pp. 346–373; 1944.

For all four primary phosphates and arsenates the piezoelectric constants d_{14} and d_{36}, as well as dielectric and elastic constants, were measured at 27 degrees centigrade by the converse piezoelectric effect at 60 cycles per second. So far as these results overlapped those of the foregoing references, there was satisfactory agreement.

(306) H. Jaffe, "Piezoelectric studies of primary phosphates and arsenates," *Bull. Amer. Phys. Soc.*, vol. 20, p. 5; January 19, 1945.

On the theoretical side, a calculation of e_{14} for zinc blende from atomic data alone was made for the first time. The result was reasonably close to the observed value. Problems on the vibrations of crystal plates were attacked by several investigators.

(307) R. Bechmann, "Natural vibrations of a rectangular quartz parallelepiped," *Zeit. für Phys.*, vol. 122, pp. 510–526; May, 1944.
(308) H. Ekstein, "High frequency vibrations of thin crystal plates," *Phys. Rev.*, vol. 68, pp. 11–23; July, 1945.
(309) H. Jaffe, "Calculation of the piezoelectric effect in ionic lattices of the zinc blende type," *Phys. Rev.*, vol. 66, pp. 357–358, 1944.
(310) H. Mähly, "Natural vibrations of thin square crystal plates," *Helv. Phys. Acta*, vol. 18, pp. 248–251; 1945.

A number of authors discussed the axes of quartz, the indexing of quartz faces, and the etch patterns on quartz crystals. Mention may be made of the following:

(311) Choong Shin-Piaw, "New etching pattern of quartz and its uses for the determination of electric axes and the detection of crystalline defects," *Jour. Opt. Soc. Amer.*, vol. 35, pp. 552–558; August, 1945.
(312) Austin F. Rogers, "Physical axes of reference and geometrical axes of reference for quartz," *Amer. Jour. Sci.*, vol. 243, pp. 384–392; July, 1945.

The year marked the closing down of the phenomenal production of quartz crystal units for military uses which attained a rate of 30,000,000 crystal units per year and a total wartime production of approximately 75,000,000. These figures are to be compared with a production of 50 to 75 thousand crystal units per year prior to the war.

The latter part of the production period witnessed several symposiums and technical sessions devoted to piezoelectric crystals. In addition to those held under military auspices in connection with the production program, a symposium on quartz crystals formed a part of the program of the American Association for the Advancement of Science at Cleveland, September 12, 1944. Papers at this session were presented by a number of physicists, geologists, and radio engineers who were actively concerned in the wartime production problem. Abstracts were printed in the program of the meeting. A technical session of the 1945 Winter Technical Meeting of the I.R.E., January 24 to 27, 1945 (see January, 1945, issue of PROCEEDINGS of the I.R.E. for titles and abstracts) was devoted to quartz-crystal progress. Although most of the papers presented at the two sessions referred to have not appeared in print, some of the material appeared in papers by the same authors in the May–June issue of the *American Mineralogist* for 1945. This issue contained an extensive series of papers which were reprinted under the title, "Symposium on Quartz Oscillator-Plates." This symposium reviewed the wartime production of quartz crystals, their radio-circuit application, the geology of principal quartz deposits, the selection of the grade of quartz for radio uses, techniques in fabrication, and the development of production tools. Of special interest from its fundamental physical implications is the effect of X-ray irradiation on the frequency of quartz-crystal plates.

(313) Clifford Frondel, "History of the quartz oscillator-plate industry, 1941–1944," *Amer. Mineralogist*, vol. 30, pp. 205–213. May–June, 1945.
(314) Karl S. Van Dyke, "The piezoelectric quartz resonator," *Amer. Mineralogist*, vol. 30, pp. 214–244; May–June, 1945.
(315) Richard E. Stoiber, Carl Tolman, and Robert D. Butler, "Geology of quartz crystal deposits," *Amer. Mineralogist*, vol. 30, pp. 245–268; May–June, 1945.
(316) Samuel G. Gordon, "The inspection and grading of quartz," *Amer. Mineralogist*, vol. 30, pp. 269–290; May–June, 1945.
(317) Joseph S. Lukesh, "The effect of imperfections on the usability of quartz for oscillator-plates," *Amer. Mineralogist*, vol. 30, pp. 291–295; May–June, 1945.
(318) William Parrish and Samuel G. Gordon, "Orientation techniques for the manufacture of quartz oscillator-plates," *Amer. Mineralogist*, vol. 30, pp. 296–325; May–June, 1945.
(319) William Parrish and Samuel G. Gordon, "Precise angular control of quartz-cutting by X-rays," *Amer. Mineralogist*, vol. 30, pp. 326–346; May–June, 1945.
(320) Samuel G. Gordon and William Parrish, "Cutting schemes for quartz crystals," *Amer. Mineralogist*, vol. 30, pp. 347–370; May–June, 1945.
(321) William Parrish, "Methods and equipment for sawing quartz crystals," *Amer. Mineralogist*, vol. 30, pp. 371–388; May–June, 1945.
(322) William Parrish, "Machine lapping of quartz oscillator-plates," *Amer. Mineralogist*, vol. 30, pp. 389–415; May–June, 1945.
(323) Clifford Frondel, "Final frequency adjustment of quartz

oscillator-plates," *Amer. Mineralogist*, vol. 30, pp. 416–431; May–June, 1945.
(324) Clifford Frondel, "Effect of radiation on the elasticity of quartz," *Amer. Mineralogist*, vol. 30, pp. 432–446; May–June, 1945.
(325) Clifford Frondel, "Secondary Dauphiné twinning in quartz," *Amer. Mineralogist*, vol. 30, pp. 447–461; May–June, 1945.
(326) There is appended to these papers a "Glossary of terms used in the quartz oscillator-plate industry," *Amer. Mineralogist*, vol. 30, pp. 461–468; May–June, 1945.

A session of the Metropolitan Section of the American Physical Society, November 9, 1945, was devoted to a series of seven papers on piezoelectric crystals, emphasizing synthetic substitutes for quartz and Rochelle salt, as well as the problem of detwinning low-grade quartz. (Abstracts printed in program of meeting.)

Prominent in manufacturing and specification considerations and in the use of quartz-crystal units has been the problem of the aging of crystal plates, particularly the deterioration of crystal surfaces which have been produced by abrasive action, the method of etching crystal plates to frequency as a means of preventing aging, and the predimensioning of plates in order to avoid critical internal elastic coupling. Papers on the aging phenomenon (not yet in print) were read at a number of the technical sessions on crystals. One such treatment was given wide circulation as a Signal Corps document.

(327) V. E. Bottom, "Aging of quartz crystal units," Engineering Memorandum No. 4 of Camp Coles Signal Laboratory; June 29 1944.

Miss E. J. Armstrong presented at the Cleveland Symposium an important review of X-ray studies of surface layers of crystals with special reference to quartz and to the aging of its surfaces, but this has so far appeared in print only as a brief abstract in the program of the meeting. A review of predimensioning as practiced by one manufacturer was published as follows:

(328) B. P. Haines, C. D. O'Neal, and S. A. Robinson, "Predimensioning quartz crystal plates," *Electronics*, vol. 18, pp. 112–119; June, 1945.

A sound motion picture in color, "Crystals Go to War," prepared by Reeves Sound Laboratories, New York City, in 1943, and in a new edition in 1945, illustrated production techniques in one crystal-manufacturing plant and was shown widely. Photography was by André LaVarre.

Papers on the measurement of the intrinsic properties of crystal units and on instrumentation for crystal measurement indicated that progress was being made in the direction of replacing arbitrary oscillation tests of crystal units for frequency control by the specification of their intrinsic properties in terms of conventional electric circuit quantities. The formalization of United States Government Joint Army-Navy specifications for certain large production units and the interest in the intrinsic properties of crystal units as circuit elements indicated considerable progress in the direction of standardization of high-frequency crystals.

(329) I. E. Fair, "Piezoelectric crystals in oscillator circuits," *Bell Sys. Tech. Jour.*, vol. 24, pp. 161–216; April, 1945.
(330) C. W. Harrison, "The measurement of the performance index of quartz plates," *Bell Sys. Tech. Jour.*, vol. 24, pp. 17–252; April, 1945.
(331) K. S. Van Dyke, "The standardization of quartz-crystal units, PROC. I.R.E., vol. 33, pp. 15–20; January, 1945.

Electroacoustics

During 1945, a number of advances were made in the field of electroacoustics, both for military and for non-military applications.

Some new microphones, sound-reproducing systems. and combinations thereof were announced for general use. These include improved standard instruments, announcing systems, circuit arrangements, particularly for higher fidelity or other special characteristics, special devices to aid in making acoustic calibrations, and devices using electroacoustic means for making various industrial tests. In this general field were the following papers:

(332) W. W. Brockway and D. C. Brockway, "Air terminal sound system," *Electronics*, vol. 18, pp. 138–141; June, 1945.
(333) Theodore E. Campbell, "Microphone input circuit," *Radio News*, vol. 33, pp. 49, 134; January, 1945.
(334) F. Earle Clark, "Quartz crystals—today and tomorrow," *Radio News*, vol. 34, pp. 45, 145–146; September, 1945.
(335) Nicholas B. Cook, "Phasing of loud speakers," *Radio News*, vol. 33, pp. 30–31, 126; April, 1945.
(336) R. W. Crane, "Audio mixer design," *Electronics*, vol. 18, pp. 120–121; June, 1945.
(337) R. W. Crane, "Suggestions for design of volume expanders," *Electronics*, vol. 18, pp. 236, 240, 244, 248, 252; May, 1945.
(338) R. W. Ehrlich, "Volume expander design," *Electronics*, vol. 18 pp. 124–127; December, 1945.
(339) G. Grammer, "Bass boost," *QST*, vol. 29, pp. 35–38; July, 1945.
(340) Erwin Griebe, "Supersonic echo depth indicators," *Radio News, Radio-Electronic Eng. Dept.*, vol. 5, pp. 5–7, 41–43; July, 1945.
(341) R. V. L. Hartley, "Production of inharmonic subfrequencies by a loud speaker," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 203–205; January, 1945.
(342) E. H. Hartnell, "A home-made intercommunicating system," *QST*, vol. 29, pp. 46–47; January, 1945.
(343) R. K. Hellmann, "Curve-tracer for acoustic devices," *Electronics*, vol. 18, pp. 130–133; December, 1945.
(344) J. C. Hoadley, "Audio oscillators and their applications," *Radio News*, vol. 34, pp. 29, 138–142; September, 1945.
(345) Paul K. Hudson, "Calibration of decibel meters," *Communications*, vol. 25, pp. 58–59, 86; July, 1945.
(346) R. S. Jerrett, "The acoustic strain gage," *Jour. Sci. Instr.*, vol. 22, pp. 29–34; February, 1945.
(347) L. W. Labaw, "Curved quartz crystals as supersonic generators," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 237–245; April, 1945.
(348) C. J. Leipert, "An extended-range audio oscillator," *QST*, vol. 29, pp. 24–26, 84; February, 1945.
(349) A. Liebscher, "The audio chanalyst," *Radio News*, vol. 34, pp. 32–34, 92, 94, 96, 98, 100; December, 1945.
(350) W. J. Lloyd, and D. E. L. Shorter, "A war correspondent's recorder at BBC: Disc-recording unit," *Communications*, vol. 25, pp. 33–35, 68–69; February, 1945.
(351) H. Mark, "Some applications of ultrasonics in high-polymer research," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 183–187; January, 1945.
(352) F. Massa, "A working standard for sound pressure measurements," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 29–34; July, 1945.
(353) W. F. Meeker and F. H. Slaymaker, "A wide range adjustable acoustic impedance," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 178–182; January, 1945.
(354) B. M. H. Michel, "The design of loudspeaker systems," *Radio News, Radio-Electronic Eng. Dept.*, vol. 4, pp. 3–6, 38–41; June, 1945.
(355) Willard Moody, "Servicing public address equipment," *Radio News*, vol. 33, pp. 46–48, 110, 112, 114; January, 1945.
(356) B. Olney, F. H. Slaymaker, and W. F. Meeker, "The dipole microphone," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 172–177; January, 1945.
(357) G. N. Patchett, "A new versatile tone control circuit," *Wireless World*, vol. 51, pp. 71–74; March, 1945; pp. 106–109; April, 1945.
(358) P. S. Rand, "A high-gain A.C.-D.C. audio amplifier," *QST*, vol. 29, pp. 32–33, 84; January, 1945.

(359) Rogelio P. McLoughlin, translated by Neil E. Handel, "Frequency standard for use at high and low frequencies," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 46–70; July, 1945.
(360) Robert G. Rowe, "Ultrasonic communications," *Radio News*, vol. 34, pp. 48–49, 118, 120, 122; October, 1945.
(361) Arthur J. Sanial, "Acoustic feedback reduction by increased directivity in electric megaphones," *Communications*, vol. 25, pp. 62–64; September, 1945.
(362) Arthur J. Sanial, "Electric megaphones," *Communications*, vol. 25, pp. 33–35, 64–65, 68–69, 76–80; July, 1945.
(363) W. Saraga, "An electronic musical instrument," *Electronic Eng.*, vol. 17, pp. 601–603; July, 1945.
(364) P. D. Saw, "Electronic sound effects," *Electronic Eng.*, vol. 17, pp. 580–584; July, 1945.
(365) H. H. Scott, "Audible audio distortion," *Electronics*, vol. 18, pp. 126–131; January, 1945.
(366) R. F. Scott, "Speech amplifiers," *Radio Craft*, vol. 6, p. 218; January; p. 289; February; pp. 354, 378; March; pp. 423, 441; April; pp. 491, 523; May, 1945.
(367) H. B. Shaper, "Frequency-response curve tracer," *Electronics*, vol. 18, pp. 118–121; March, 1945.
(368) Frederick W. Smith, Jr., "Resonant loudspeaker enclosure design," *Communications*, vol. 25, pp. 35–37; 77–78, August, 1945.
(369) C. Stevens, "Unique volume expander and compressor," *Radio News*, vol. 34, pp. 50–51, 94; July, 1945.
(370) K. R. Sturley, "Low-frequency amplification," *Electronic Eng.*, vol. 17, pp. 236–238, 247; November, 1944; pp. 290–293; December, 1944; pp. 335–338; January, 1945; pp. 378–381; February, 1945; pp. 429–431; March, 1945; pp. 470–472; April, 1945; pp. 510–513; May, 1945.
(371) G. J. Thiessen, "R-C filter circuits," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 275–279; April, 1945.
(372) J. A. Weller, "A volume limiter for leased-line service," *Bell Lab. Rec.*, vol. 23, pp. 72–75; March, 1945.

Many electroacoustic devices were developed for the armed forces. Information regarding a large number of these is still unpublished for military reasons and during 1946 it is expected that there will develop a large list of such devices. Some that were described during 1945 are listed as follows:

(373) L. B. Cooke, "The voice of ship command," *Bell Lab. Rec.*, vol. 23, pp. 241–245; July, 1945.
(374) H. W. Duffield, "A 9-speaker battle announcing system," *Communications*, vol. 25, pp. 48–50; October, 1945.
(375) J. C. Hoadley, "Wartime speaker enclosures," *Radio News*, vol. 34, pp. 48–49, 150; July, 1945.
(376) B. E. Phelps, "Motor noise unit for aircraft trainer," *Electronics*, vol. 18, pp. 96–99; August, 1945.

One device of particular significance for industrial application was the supersonic reflectoscope.

(377) F. A. Firestone, "The supersonic reflectoscope for interior inspection," *Metal Progress*, p. 505; September, 1945.

New equipment and techniques were announced for disk, wire, and film recordings.

(378) W. S. Backman, "Phonograph dynamics," *Electronic Indus.*, vol. 4, pp. 86–89, 124, 128, 190; July, 1945.
(379) B. B. Bauer, "Notes on distortion in phonograph reproduction caused by needle wear," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 246–253; April, 1945.
(380) B. B. Bauer, "Tracking angle in phonograph pickups," *Electronics*, vol. 18, pp. 110–115; March, 1945.
(381) N. L. Chalfin, "Phono head balance," *Electronic Indus.*, vol. 4, pp. 102–103, 138, 142; September, 1945.
(382) R. H. Cricks, "Sound reproduction amplifiers," *International Projectionist*, vol. 20, pp. 10, 12; June, 1945.
(383) R. N. Farr, "Sound on the record," *Sci. News Letter*, vol. 47, pp. 362–364, 366; June 9, 1945.
(384) L. C. Holmes and D. L. Clark, "Supersonic bias for magnetic recording," *Electronics*, vol. 18, pp. 126–136; July, 1945.
(385) E. W. Kellogg, "The ABC of photographic sound recording," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 151–194; March, 1945.
(386) T. Lindenberg, Jr., "Moving-coil pickup design," *Electronics*, vol. 18, pp. 108–110; June, 1945.
(387) W. C. Miller, "The PH-346A recording equipment," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 75–96; February, 1945.
(388) W. A. Mueller and M. Rettinger, "Anecdotal history of sound recording technique," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 48–53; July, 1945.
(389) "Multi-channel sound recording on film," *Electronic Indus.*, vol. 4, pp. 92–93, 158, 160; April, 1945.
(390) P. Peters, "New portable disc recorder," *Radio News*, vol. 33, pp. 35, 142, 144–145; April, 1945.
(391) N. C. Pickering, "Improving recordings," *Electronic Indus.*, vol. 4, pp. 82–84, 206, 210, 214; October, 1945.
(392) I. Queen, "Noiseless recording," *Radio-Craft*, vol. 16, pp. 274, 320–321; February, 1945.
(393) H E. Roys, "Experience with an FM calibrator for disk recording units," *Jour. Soc. Mot. Pic. Eng.*, vol. 44, pp. 461–471; June, 1945.
(394) Robert Stone, "Business recording equipment," *Radio News*, vol. 34, pp. 32–34, 100, 102–104, 106; November, 1945.
(395) Carl E. Winter, "Magnetic tape recording," *Radio News*, vol. 33, pp. 32–34, 138, 140–141; June, 1945.

Among the developments in hearing aids, audiometry, and miscellaneous medical applications are those described in the following papers:

(396) H. A. Carter, "The consideration of hearing aids and audiometers by the Council on Physical Medicine," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 203–205; January, 1945.
(397) V. E. Eitzen, "Hearing-aid microphone design," *Radio News*, Radio-Electronic Eng. Dept., vol. 4, pp. 13–15, 30, 32; May, 1945.
(398) J. D. Harris, "Group audiometry," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 73–76; July, 1945.
(399) C. J. LeBel, "Hearing aid technic," *Electronic Indus.*, vol. 4, pp. 104–106, 198, 200–202, 204–205; January, 1945.
(400) K. Lowy, "Some experimental evidence for peripheral auditory masking," *Jour Acous. Soc. Amer.*, vol. 16, pp. 197–202; January, 1945.
(401) F. E. Planer and E. A. Marland, "Negative feedback in hearing aid amplifiers," *Electronic Eng.*, vol. 17, pp. 450–453, 455; April, 1945.
(402) Maurice B. Rappaport, "Development of cardiac diagnostic instruments," *Radio News*, vol. 34, pp. 25–28, 106, 108, 110, 112; September, 1945.
(403) M. B. A. Schier, "Clinical phenomena in conductive media: the individual earpiece," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 77–82; July, 1945.
(404) "Tentative code for measurement of performance of hearing aids," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 144–150; October, 1945.
(405) N. A. Watson, "Air- and bone-conduction audio testing assembly," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 194–196; January, 1945.

A number of purely analytical studies was made extending the theory of operation of various acoustic radiating elements, as well as studies of various field problems including conduction through ducts. One significant feature was the increased emphasis given to reciprocity methods of calibrating instruments. Among the studies presented were:

(406) Piero Giorgio Bordoni, "The conical sound source," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 123–126; October, 1945.
(407) E. Fisher, "Attenuation of sound in circular ducts," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 121–122; October, 1945.
(408) Leslie L. Foldy and Henry Primakoff, "A general theory of passive linear electroacoustic transducers and the electroacoustic reciprocity theorems," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 109–120; October, 1945.
(409) Charles E. Harrison, "Electrical-acoustical equivalents," *Communications*, vol. 25, pp. 44–45; June, 1945.
(410) R. Clark Jones, "On the theory of the directional patterns of continuous source distributions on a plane surface," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 147–171; January, 1945.
(411) A. Kahn, "How microphones work," *QST*, vol. 29, pp. 34–37; September, 1945.
(412) P. W. Klipsch, "A note on acoustic horns," PROC. I.R.E., vol. 33, pp. 447–449; July, 1945.
(413) L. W. Labaw, "Wave-front determination in a unidirectional supersonic beam," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 19–23; July, 1945.
(414) C. T. Molloy and E. Honigman, "Attenuation of sound in lined circular ducts," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 267–272; April, 1945.
(415) George M. Nixon, "'Higher fidelity' in sound transmission and reproduction," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 132–135; October, 1945.

(416) R. A. Scott, "An investigation of the performance of the Raleigh disc," *Proc. Roy. Soc.*, ser. A, vol. 183, pp. 296–316; February 22, 1945.
(417) Eugene Tsung-Yueh Hsu, "Measurement of supersonic absorption in water by the balance method with mechanical integration," *Jour. Acous. Soc. Amer.*, vol. 17, pp. 127–131; October, 1945.
(418) A. O. Williams, Jr., and L. W. Labaw, "Acoustic intensity distribution from a 'piston' source," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 231–236; April, 1945.

Several significant papers were published on matters which had been previously classified. Included in these were:

(419) C. J. Burbank, "Acoustic reflections from triplanes, spheres, and disks," announced for presentation to the American Physical Society in January, 1946.
(420) W. L. Bond, "Methods of orienting and cutting synthetic crystals," presented to Metropolitan Section, American Physical Society, Columbia University, November 9, 1945.
(421) Hans Jaffe, "The order of magnitude of piezoelectric effects," presented to Metropolitan Section, American Physical Society, Columbia University, November 9, 1945.
(422) G. W. Willard, "Ultrasonic interference at angular reflection," presented to Metropolitan Section, American Physical Society, Columbia University, November 10, 1945.

Circuits

Network Analysis and Synthesis

A number of papers, significant because of their value in contributing to the advancement of fundamental theoretical knowledge in connection with the general problems of analysis and synthesis appeared during 1945. In a few appropriate instances, attention is drawn, in the following summary, to papers appearing in 1944.

On the subject of transient response of networks the most significant contribution of recent years is contained in the paper

(423) H. E. Kallmann, R. E. Spencer, and C. P. Singer, "Transient response," PROC. I.R.E., vol. 33, pp. 169–195; March, 1945.

An analysis is given here of the step-function response of a variety of actual and ideal networks suitable as coupling networks in television amplifiers. A principal feature of the investigation is the determination of an ideal characteristic yielding a transient response exhibiting uniform stretch properties when identical stages are cascaded. This result readily permits the evaluation of a design for stated over-all tolerances.

A second paper concerned with the basic principles of transient response appeared late in 1944.

(424) W. W. Hansen, "Transient response of wide-band amplifiers," *Electronic Indus.*, vol. 3, pp. 80–82, 218, 220; November, 1944.

The paper suggests that the quality of the transient response of low-pass and band-pass networks be expressed in terms of a quantity (called "transient bandwidth") which is essentially the reciprocal of the mean squared error between the impulse response and the impulse itself. This index is compared with the commonly employed bandwidth (of the steady-state response function) for singlestage and multistage wide-band amplifiers employing the more commonly considered types of coupling networks.

Of theoretical interest in the field of network synthesis is a paper concerned with the problem of showing that a transfer function having an amplitude given by the probability function, although theoretically not realizable, may nevertheless be approximated asymptotically by cascading an unlimited number of simple constant-resistance networks; the joker, however, being that the resulting time delay approaches infinity. The authors point out that one may ordinarily content oneself with a moderately good degree of approximation and thus obtain for certain applications a desired form of response for pulses which themselves have the form of the probability function.

(425) F. F. Roberts and J. C. Simmonds, "The physical realizability of electrical networks having prescribed characteristics, with particular reference to those of the probability function type," *Phil. Mag.*, vol. 35, pp. 778–783; November, 1944.

It has long been known that the real and imaginary parts of an impedance or propagation function are so-called conjugate potential functions and that an electrolytic tank may be used to study the properties of such functions. That this technique may effectively be employed in the evaluation of impedances as functions of frequency when their zeros and poles are specified is shown in the following paper:

(426) W. W. Hansen and O. C. Lundstrom, "Experimental determination of impedance functions by the use of an electrolytic tank," PROC. I.R.E., vol. 33, pp. 528–534; August, 1945.

In the design of coupling networks for wide-band amplifiers, the maximum gain-bandwidth product obtainable is limited by the parasitic shunt capacitances of the associated tubes. H. A. Wheeler has, in the past, made notable contributions toward evaluating the ultimate limit obtainable, and H. W. Bode (see comments on his recent book below) by applying synthesis procedures, succeeded in obtaining the correct theoretical upper limit as well as developing a method of design whereby one may practically find networks which yield any desired approximation to this limit. In the paper

(427) W. W. Hansen, "On maximum gain-bandwidth product in amplifiers," *Jour. Appl. Phys.*, vol. 16, pp. 528–534; September, 1945,

the author shows how these results may be obtained more simply through reasoning in terms of potential theory, although his conclusions in the case of a four-terminal interstage network were not obtained by this method alone but are a substantiation of results given by Bode. He carries his analysis further than has heretofore been done in considering the additional advantage gained through the use of stagger-tuned stages.

Much heretofore unpublished material relating to network analysis and synthesis has appeared in the book

(428) H. W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Company, Inc., New York, N. Y., 1945.

The discussion relating to passive network synthesis is restricted to that portion having a more immediate bearing upon the problem of feedback-amplifier design, this being the primary topic. A very complete discussion is given of the relations between the real and imaginary parts of an impedance or propagation function. While a significant application of these results is that dealing

with the design of interstage coupling networks and the maximum gain-bandwidth limitation mentioned above, their use is exhaustively discussed in connection with the stability problem arising in the design of feedback amplifiers.

A topic of interest to those concerned with developing synthesis procedures applicable to problems dealing with ultra-high frequencies is that of determining whether properties of lumped-circuit impedances apply also to impedances of wave-guide sections and cavities. A contribution showing that this is the case for lossless cavities is given in the paper

(429) W. R. MacLean, "The reactance theorem for a resonator," PROC. I.R.E., vol. 33, pp. 539–541; August, 1945.

In the design of servomechanisms, the techniques of network synthesis are gradually being more fully applied. A discussion from this point of view, using a very strong mathematic approach and making full use of the methods developed by Bode, is given in the book

(430) L. A. MacColl, "Fundamental theory of servomechanisms," D. Van Nostrand Company, Inc., New York, N. Y., 1945.

An additional contribution in this field in which the servo problem is analyzed in terms of the methods of conventional transmission theory is given in the paper

(431) Enoch B. Ferrell, "The servo problem as a transmission problem," PROC. I.R.E., vol. 33, pp. 763–767; November, 1945.

In addition to the above contributions which deal with topics having a more direct bearing upon the advancement and application of knowledge in circuit theory generally, the following additional papers on miscellaneous specialized subjects may also be mentioned.

An adaptation of the twin-T circuit in a feedback amplifier is shown to yield a method of designing satisfactory filter circuits with resistance and capacitance elements alone in the paper

(432) G. J. Thiessen, "R-C filter circuits," *Jour. Acous. Soc. Amer.*, vol. 16, pp. 275–279; April, 1945.

A practical method of obtaining stable negative circuit elements is discussed in the following:

(433) E. L. Ginzton, "Stabilized negative impedances," *Electronics*, vol. 18, pp. 140–144, 146, 148, 150; July, 1945; pp. 138–144, 146, 148; August, 1945.

A discussion of the properties and possible uses of the "butterfly" circuit as a resonator for frequencies in the range 100 to 1000 megacycles is given by

(434) Edward Karplus, "Wide-range tuned circuits and oscillators for high frequencies," PROC. I.R.E., vol. 33, pp. 426–441; July, 1945.

The familiar image-parameter methods of linear-network analysis are applied to the problem of mixers to determine conditions for optimum performance in the paper

(435) L. C. Peterson and F. B. Llewellyn, "The performance and measurement of mixers in terms of linear-network theory," PROC. I.R.E., vol. 33, pp. 458–476; July, 1945.

A study of the distortion introduced by the tuned circuits of a frequency-modulation system is given by

(436) David Lawrence Jaffe, "A theoretical and experimental investigation of tuned-circuit distortion in frequency-modulation systems," PROC. I.R.E., vol. 33, pp. 318–333; May, 1945.

Standards

During the closing months of the war and for the remainder of the year 1945, progress was made in reactivating the I.R.E. standardization program, which, during the war years, had reflected the preoccupation with the war effort. Through joint efforts and interest, the Institute's standardization organization will cooperate much more closely than ever before with other organizations having a community of interest in common fields of activity. In the closing months of the year these plans were being placed into effect, particularly with respect to the Radio Manufacturers Association and the American Institute of Electrical Engineers. The I.R.E. standardization program will be accelerated through the addition of a full-time Technical Secretary, an office which was created by the Board of Directors during this year.

Acknowledgment

As in previous years, this summary for 1945 covers generally, for the subjects dealt with, developments described in publications issued up to about the first of November. It is subject, as recent reviews have been, to the fact that publication and the distribution of publications have been limited by the circumstances of war. The material has been prepared by members of the 1945 Annual Review Committee of the Institute, edited and co-ordinated by Laurens E. Whittemore, Chairman,and Keith Henney, H. A. Wheeler, I. S. Coggeshall, and J. Warren Horton, Members-at-Large.

The other members of the Annual Review Committee for 1945 and the committees of the Institute of which they are chairmen are as follows:

R. S. Burnap	Electron Tubes
W. G. Cady	Piezoelectric Crystals
P. S. Carter	Antennas
C. C. Chambers	Frequency Modulation
W. T. Cooke	Railroad and Vehicular Communications
D. E. Foster	Radio Receivers
E. A. Guillemin	Circuits
R. F. Guy	Standards
I. J. Kaar	Television
A. C. Keller	Electroacoustics
J. F. Morrison	Radio Transmitters
E. W. Schafer	Symbols
J. A. Stratton	Radio Wave Propagation and Utilization
C. J. Young	Facsimile
P. Zottu	Industrial Electronics

The chairmen of the above committees wish to acknowledge the assistance given them in many cases by individual members of the committees.

Those New Frontiers*

PAUL A. PORTER†

IN THE PAST 25 years, the American radio engineer has built the largest broadcasting system and the largest international radio-communications system in the world.

The major role that the radio engineer has played in our life in recent years, and especially in wartime, has made his profession one of the more glamorous of our times. A grateful and admiring population, awed by the miracles already produced and excited by the promise of other miracles still shrouded in secrecy, is in a mood to unhook the horses from your carriages and haul your electronic heroes through the streets. The rise of the radio engineer in the esteem of the whole fraternity of learned professions has been equally marked.

But this review of past successes does not by any means indicate that your profession has now completed its life cycle and that you must convert to some other occupation if you are to continue to serve society as well as earn your daily bread. On the contrary, this 1946 Meeting of The Institute of Radio Engineers finds radio moving rapidly towards revolutionary developments. All your achievements of the past have been merely a prologue to a dynamic, ever-expanding future. In the next quarter of a century, I confidently expect to see your accomplishments tripled or quadrupled.

The house of radio has, of course, been drastically expanded during the war. The usable spectrum space has been extended from 300 megacycles to more than 30,000 megacycles. Instead of the ivy-covered cottage of the simple prewar days, the radio engineer now has a skyscraper. We haven't found the keys to all the rooms yet and there is some difference of opinion among the prospective tenants over the desirability of the upstairs floors versus the lower floors for their special needs; but nevertheless, no landlord has a longer waiting list of applicants than the Federal Communications Commission.

As soon as it became apparent that the unprecedented technical advances during the war were going to provide more operating space in the radio spectrum, the Federal Communications Commission, in conjunction with industry, with special co-operation from this organization, began laying plans for a reallocation of frequencies that would provide channels for a number of new radio services and for the expansion of existing ones.

That work has now been largely completed and while many policy questions still remain to be decided, such great new fields of activity have been opened up that the radio industry is now enjoying a phenomenal boom, with the radio engineer riding the crest of the wave.

Let's look at some of the many fields in which radio is expanding: In standard broadcasting, there are 940 stations on the air, and 64 construction permits for new stations have been issued. We have 525 applications on file for new amplitude-modulation stations, 250 applications for changes in existing stations, and more continue to come in daily.

Frequency modulation, whose qualities of life-like high-fidelity reception will provide a superior broadcasting service, has attracted the support of both the present standard broadcasters and newcomers. More than 750 applications for new frequency-modulation stations have been received. Conditional grants have been issued to nearly 300 of them. I anticipate that in a few years' time several thousand such stations will be constructed. It is now apparent that, eventually, frequency-modulation broadcasting will largely supplant the present system of standard broadcasting especially for regional and local service. Radio engineers can contribute much to the solid growth of frequency modulation by insisting on receiver design that will give the listener the fullest benefit of frequency-modulation's superior qualities.

The immediate development of television was given the green light by the Commission with the allocation of 13 channels below 300 megacycles, the allotment of channels over the nation, and the issuance of standards of good engineering practice. More than 150 applicants have filed for television stations in these channels. In addition, the Commission is encouraging the fullest experimentation with wide-channel color television in the higher frequencies.

Experimentation is also going forward in facsimile broadcasting.

All these new and expanded types of broadcasting will demand the expenditure of hundreds of millions of dollars for transmitting and receiving equipment, not to mention the expenditures for program services and other operational expenses.

This new era in communications is witnessing the introduction of beam radio into domestic telegraph and telephone operation. The revolutionary modernization program which Western Union has embarked upon calls for the construction of beam radio between the larger cities to replace its overhead pole-and-wire plant. The use of short-wave radio in telephone operations should extend service to thousands of rural residents, who now do not have telephone service because wire lines are not accessible. Four other companies are experimenting with radio-relay systems.

Westinghouse has been granted a license to experiment with its stratovision relay and broadcasting system using airplanes circling aloft as transmitter sites.

* Decimal classification: R040. Original manuscript received by the Institute, February 5, 1946. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 25, 1946.

† At the time of this address Mr. Porter was Chairman of the Federal Communications Commission, Washington, D. C. He later became Chairman of the Office of Price Administration.

And, of course, the coaxial-cable system being rapidly pushed forward by the American Telephone and Telegraph Company will speed the growth of television network service.

Short-wave radio will be used in the General Mobile Service which will provide two-way telephone communication for various types of mobile units. A limited number of experimental licenses is being issued by the Commission to determine the best operating plan for this service. Bell System companies have already filed applications for experimental urban mobile stations in 27 cities and have under consideration applications for additional experimental stations in 42 other cities.

The American Telephone and Telegraph Company has advised the Commission that it expects at least 10,000 doctors' cars, ambulances, buses, taxicabs, and commercial vehicles to be equipped with two-way radio within the next two years, in New York alone.

Regular two-way radio service was authorized for the use of the nation's railroads by the Commission last December 31st, after considerable experimentation and after public hearings had been held. The good old days of brakemen crawling over the tops of trains or stumbling through the darkness and the blizzards to protect their trains seem on their way out, as the short wave comes in. The Commission has been advised that 52 railroads plan to install radio equipment as soon as possible, to promote safety and efficiency. We anticipate that every class I railroad in the country will be equipped within the next five years. Many of them will have more than 100 two-way stations each.

The walkie-talkie will soon be putting on civilian clothes when the Commission authorizes the establishment of the Citizens Radiocommunication Service. This will permit anyone to be licensed to use this two-way type of radio for his personal convenience or to aid in running his business. We expect wide use by farmers, doctors, hunters, fishermen, dairies, express companies, laundries, and other individuals or concerns who do not require an exclusive frequency.

The radio "ham" who was silenced all during the war has been restored his historic privilege of chinning with other like-minded enthusiasts over the minutiae of their hobby. At present, about 60,000 amateurs hold licenses but we expect that number to go up to 100,000 because of the huge number of men who learned radio while in the service.

The expansion of the Aviation Radio Services will, of course, be tremendous. Whereas there are at present only 3000 United States aircraft stations, we expect at least 26,000 by a year from now. Some experts predict that all itinerant aircraft using established airways will be required to carry radio in a few years because of the increasing congestion of traffic. There will also be a rapid increase in ground stations.

The wartime mushrooming of the nation's shipbuilding program and the allocation of additional very-high-frequency channels for maritime use insures a sharp rise in the number of ship-radio installations, especially in the coastal-harbor service.

Also, radio is destined to become a bigger police weapon than ever before. While the value of radio in fighting crime is universally conceded, the wartime shortages of equipment have not permitted the fullest utilization of this powerful aid. I think you will be surprised to learn, as I was recently, that the police of only 1300 of the 16,500 incorporated cities of the nation are equipped with police radio—an indication of the possibilities of future development. Fire departments were given their own frequencies in our allocation plan, and we anticipate that 5000 of them eventually will have their own systems.

The Commission reached a reconversion milestone on December 13th when it issued its first license—an experimental license—for the civilian use of radar. It also recently granted its first license for the use of radio for irrigation control. What nonmilitary use will be made of such inventions as loran, shoran, the huff-duff, and so on, we cannot now estimate.

Radio will be used in many industrial processes, especially in heat treating. The latest flash from this radio front brings tidings of a slot machine which will cook hot dogs by radio waves and will deliver them in a sandwich complete with mustard for one dime.

A vast new field for radio engineering lies in the refinement of international radio-communications equipment. The scarcity of frequencies makes such refinements absolutely necessary. I have in mind such wartime developments as multichannel transmission, the carrier shift system and improvements in directional antennas.

New wonders, still unsuspected by most of us laymen, are no doubt locked in many a bosom in this distinguished assembly of radio engineers. And these, of course, do not include the inventions already perfected but which are still kept a military secret. But this much I can tell you: because of military demands and also because of the availability of federal funds for these wartime research projects, the number of experimental stations authorized by the Commission last year jumped 100 per cent. The study of technical inventions or improvements as they are declassified by the military will be a continuing responsibility of the Commission.

This bold program of experimentation, carried out under the pressure of wartime demands and financed by the federal government, has produced technical advances which we would not otherwise have had for years or for generations. That program has made it possible for you and me to enjoy in our lifetime technological improvements for a better and richer life which otherwise might not have come until we had departed these earthly shores—might not even have come in time for our children or our grandchildren to enjoy. And of course, I need not enlarge here on the new horizons that

have been opened up, particularly for the radio-engineering profession, by these great wartime co-operative technical projects.

In view of the giant strides made through this concentrated wartime effort, I am naturally highly enthusiastic over the steps now being taken to formulate a federal research program which will blaze the trail for further practical applications to improve our way of life. To me, such a program seems such a logical move toward the fuller utilization of our intellectual resources that I regret that it was not undertaken years ago. It is indeed so logical that, while there has been some disagreement as to details, the testimony of scientists, educators, industrialists, civic leaders, farm leaders, government administrators, military officials, and others before the Congress has been overwhelmingly in favor of a federally supported research program.

The keen interest displayed by the scientists is in line with the growing concern which so many of them are evincing over the social results of their discoveries. The most notable instance, of course, is the organization of the Federation of American Scientists by the men who worked on the atomic bomb—a group dedicated to political action. I was deeply impressed by the testimony of Dr. Isaiah Bowman, president of Johns Hopkins University: "The scientist cannot afford to neglect politics and the Congressman cannot afford to neglect the scientist. We are in this boat together. Each of us must use language that the other can understand; all must participate in a final judgment upon wise action."

This interest, too, is in recognition by some leaders of the profession that the members of the profession have not been as concerned as they might have been in the past with the social consequences of their endeavors. I am thinking of Morris Cooke's warning: "Notwithstanding the fact that science and engineering steadily acquire a larger place in our civilization, they all but unknowingly practice a form of isolationism which retards social progress and keeps us in many ways from realizing on the American dream of Thomas Jefferson, 'a people living in comfort on the fruits of their industry'."

The Subcommittee on War Mobilization of the Senate Military Affairs Committee, headed by Senator Kilgore, has been studying this need for more adequate research for three years, and called attention more than a year ago to the need for a continued high level of research in the postwar period with the federal government contributing such support as may be required to supplement the work of private organizations and institutions.

As a spur to research, Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, in a report to President Truman last July 5th, proposed the creation of a permanent over-all federal agency for the support of science. The President, in his message to Congress on September 6th urged early legislation for this program.

Among the organizations favoring a federal research program is the Engineers Joint Council which includes the American Institute of Electrical Engineers. Their endorsement includes this statement: "The engineering profession stands undivided back of the words of the President, that 'Progress in scientific research and development is an indispensable condition to the future welfare of and security of the Nation'." The statement adds: "It is self-evident that the size and the urgency of the problem are such that scientific research in this country no longer can be allowed to depend on the course of natural development that prevailed in the past, and to rely upon the diminishing funds of private philanthropy. A systematic and generous yearly appropriation of Government funds becomes a necessity."

No one knows better than you radio engineers the frontiers that still remain to be conquered in your particular field. These are tasks of such magnitude and of such general benefit to the entire field that no one company can or should be expected to undertake them. They are proper concerns of the federal government. It is now plain that we will have no alternative in this matter. Either research into "pure" science is to be aided by the federal government, or much of it will simply be left undone. Few people realize how great a debt we owe to the "pure" science researches of Europe for our great strides here in applied science.

I have been gratified by the general broad-gauge view taken by the nation's leaders on this matter. It has been almost unanimously conceded that, while there may be no immediate practical benefit from the proposed basic research, the long-range results will pay rich dividends, and that, in fact, such fundamental spade work is indispensable to practical application.

Having shifted from low gear to high gear in radio progress during the war, we can only maintain that speed by intensive research in a wide range of problems. For instance, we have really only begun to explore the higher reaches of the radio spectrum. If we had a public domain of comparable extent in the form of land, we would need no urging to devise ways and means of exploiting its natural resources. Yet this ethereal area of public-domain promises is susceptible to perhaps equal or greater yields. Our present knowledge of one of the most important elements in radio transmission, the ionosphere, is limited. The study of this element will afford a challenge to the best research brains in America.

One of the foremost beneficiaries, from an occupational standpoint, of the current trend toward a closer international relationship, is the radio engineer. For without fuller communications facilities such relationship cannot flourish.

The development of the United Nations Organization will demand a continuing expansion of communications facilities. In due time, there will be a World Telecommunications Conference to pave the way further for a freer flow of communications on a world-wide

basis. I have every reason to expect that the trend to co-operation, to a lowering of barriers which featured the Third Inter-American Radio Conference at Rio de Janeiro last September and the British-American conference at Bermuda last December, will also prevail at the forthcoming world conference. America and the other nations of the world must have ample, rapid, cheap communication with each other if we are to achieve the ideal of common understanding and co-operation to which we are committed. In this connection, I trust that this nation will not fail as it did after the last world war to put its house in order by a unification of its international communications facilities.

The demands of world trade and the development of an international information program by the Department of State will aid and be aided by an expansion of our international communications systems.

You now have the following immediate assignments:

1. The construction of an entirely new system of aural broadcasting, frequency modulation, complete with thousands of transmitters, millions of receivers, and nationwide networks.
2. The construction of a nationwide system of television.
3. The construction of scores of radio systems for a wide variety of uses to promote safety and efficiency.

Frequency Service Allocations*

PAUL D. MILES†, SENIOR MEMBER, I.R.E.

THE SCIENCE of frequency allocations, which was at one time very simple, has become exceedingly complex within the past few years. The first international radio conference, at Berlin in 1906, dealt with only two frequencies, namely 500 and 1000 kilocycles, and was concerned with ship-shore telegraphy exclusively. The London Conference of 1912 dealt with a slightly expanded spectrum between approximately 150 and 1000 kilocycles, but again was confined almost entirely to ship-shore communications. The development of high-frequency communications expanded the spectrum so materially that the Washington Conference of 1927 effected service allocations from 10 to 23,000 kilocycles. By the time of Madrid, 1932, this had been increased to 30,000 kilocycles, while the Cairo Conference, in 1938, extended the allocation table on a regional basis to 200,000 kilocycles.

Frequency allocations had an equally simple beginning in the United States, being first specifically treated by the Radio Communications Act of 1912, which granted limited administrative power for its enforcement to the Secretary of Commerce. The rapid growth of broadcasting in the 1920's resulted in a crisis which was resolved by the creation of the Federal Radio Commission under the Radio Act of 1927, in turn superseded by the Federal Communications Commission under the Communications Act of 1934.

The developments of the recent war lent impetus to a very rapid expansion of the radio spectrum above 200 megacycles, and gave rise to new techniques which vastly complicated frequency service allocations. Because of this situation, it became apparent by 1943 that the Government should begin preparatory studies immediately for the next world telecommunications conference. Accordingly, the Interdepartment Radio Advisory Committee[1] in August of that year appointed a subcommittee to deal exclusively with that subject and simultaneously the Federal Communications Commission designated an engineering committee to undertake parallel studies. By June of 1944, the Interdepartment Radio Advisory Committee had completed its study of the subject, had prepared a tentative international service-allocation table, and had transmitted it to the Department of State. Following a suggestion by the Chairman of the Commission in November, 1942, the Radio Technical Planning Board was established in September, 1943, to organize technical facts which would assist in the development of the radio industry in accordance with the public interest, and to advise Government, industry, and the public of its determination. In August, 1944, the Commission scheduled a general allocation hearing, to commence on September 28 of that year, to determine the present and future needs of the various nongovernment services for frequencies in the radio spectrum between 10 and 30,000,000 kilocycles. In May, 1945, the Commission, in co-operation with the Interdepartment Radio Advisory Committee, promulgated the final United States allocation plan above 25 megacycles and a tentative plan below 25 megacycles.

This unique departure in the mode of technical preparation for an international telecommunications conference was necessitated largely because the work was begun in the midst of a war when military security restrictions made it impossible to proceed in a different manner. Because of this departure it may be helpful to outline some of the principles underlying our work. In beginning our postwar planning we had the choice of disturbing the Cairo table as little as possible, or of making a fresh start in the light of modern needs. Upon considering the needs of services such as aviation, recent developments making use of techniques unknown at the

* Decimal classification: R070. Original manuscript received by the Institute, January 10, 1946. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 24, 1946.

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[1] E. M. Webster, "The interdepartment radio advisory committee," PROC. I.R.E., vol. 33, pp. 495–499; August, 1945.

time of Cairo, together with the fact that this probably would be the last opportunity for many years to make drastic changes in the allocation table, it seemed to us the better course to adopt the second alternative.

After we had determined upon the course to follow, we took up the question of shared bands in the high-frequency spectrum (3 to 30 megacycles), and decided that they should be eliminated as far as possible. It was also decided that the aeronautical mobile service should have its exclusive bands of frequencies and similarly that the maritime mobile service should have its exclusive bands. In addition, it seemed to us equally desirable to do everything possible to encourage the transfer of radio services now using medium and high frequencies to that portion of the spectrum now known as the very-high (30 to 300 megacycles), the ultra-high (300 to 3000 megacycles), or super-high (3000 to 30,000 megacycles), wherever the local nature of the service would permit, thereby materially relieving congestion in the lower part of the spectrum in order that more effective use might be made thereof for the long-distance services.

In our detailed consideration of the table below 30 megacycles, we first took up the specific frequencies to be employed by the maritime mobile service for distress and calling purposes. We made a careful study of the frequency of 500 kilocycles, to determine whether that was the optimum frequency for the purpose. The decision was reached that this frequency must be retained, but it was felt that it might be desirable to provide a second distress frequency, intended primarily for intercommunication over the seas between aircraft and ships in cases of distress. While the solution to that problem has not been finally determined, the tentative plan does provide, in addition to 500 kilocycles, a frequency in the 2-megacycle band. It also seemed desirable to us to strengthen the intent of both the Madrid and Cairo regulations to provide high frequencies for maritime calling, by specifically designating a harmonically related series for the purpose.

Turning then to the amateur problem, we replaced in the table the Cairo bands, with the single exception of the band 1750 to 2050 kilocycles which, of course, had to be eliminated because of the establishment therein during the war of loran, a high-power, long-range navigation system employing pulse emission. In addition, a new band was laid down for the amateur service in the vicinity of 21 megacycles, in partial harmonic relationship with the 7-megacycle band.

As we proceeded in building our table, we next turned to the high-frequency maritime mobile bands. It will be recalled that Cairo provides such bands in the vicinity of 4, 5, 6, 8, 11, 12, 16, and 22 megacycles. Because of the essential requirements of other services, it seemed desirable to effect a reduction, resulting in the provision of such bands in harmonic relationship as far as possible in the vicinity of 4, 6, 8, 12, 16, and 20 megacycles.

In our further work we proceeded to the consideration of high-frequency broadcasting and in that connection had the benefit of a study prepared by a special interdepartmental government committee. This study indicated that approximately 118 countries and territories were making use of the frequency range between 4 and 20 megacycles for some form of broadcasting. It indicated further that, in addition to the 105 broadcast channels available under the Cairo table, broadcast stations have been monitored from time to time on 495 other frequencies between 4 and 20 megacycles. In other words, for every useful frequency within the bands now allocated, more than 4 others have been found outside of these bands. It therefore appeared to us that to provide sufficient frequencies to permit all of the nations to operate an unlimited high-frequency broadcast service, from one third to one half of the entire high-frequency portion of the spectrum might be required. In the light of the current United States policy to maintain a high-frequency broadcast service, and one which is not inferior to that of any other nation, the only feasible solution appeared to be the continuance of the Cairo bands, recognizing that the only hope for interference-free operation of this service would be a detailed agreement among the nations concerned which would stipulate precisely which frequency or frequencies each could use and when by making full use of geographical and time-sharing factors, as well as a rigid limitation in the number of stations that each nation would operate. It is of interest to note that the Third Inter-American Radio Conference, held at Rio de Janeiro in September, 1945, unanimously adopted a resolution introduced by Brazil which recommended that a special world broadcasting conference be held, immediately following the next world telecommunications conference, to reach international agreement on the use of the frequencies available for that service.

Because of the expansion of the standard broadcast service, augmented by the growth of that service in Cuba and Mexico, a serious attempt was made to procure more spectrum space for it. While the continued need of the maritime mobile service for medium frequencies provided the limiting factor, it was found possible to extend the lower limit of the standard broadcast band to 535 kilocycles, thus providing one additional assignable frequency.

Before we leave broadcasting, I will note tropical broadcasting, an innovation introduced at Cairo in an attempt to satisfy the broadcasting needs of certain tropical areas which cannot make effective use of the standard band. Because such operations to the South of us have resulted in severe interference to our fixed and mobile communications, we intend to do everything possible to discourage this service, simultaneously urging the development of frequency-modulation broadcasting as the ultimate solution to this problem. A beginning was made by our delegation at the Rio Conference, which introduced a resolution urging immediate frequency-modulation broadcast experimentation in the tropical areas of this continent to determine to what

extent this might provide a solution for the tropical broadcast problem. This resolution was adopted unanimously by the Conference. Anything which can be done by the industry to further this objective will be of material benefit to us all.

Turning now to the aeronautical service, whose importance had been spectacularly demonstrated by the war, we had the benefit of the recommendations of another special interdepartmental committee. Adopting the recommendations of that committee as far as possible, aeronautical mobile bands have been proposed which we believe should be sufficient to provide the necessary air-ground communications for the postwar international air routes. I think it is well recognized that it was most unfortunate that the Cairo Conference did not provide route aeronautical frequencies below 6 megacycles, a deficiency that has been remedied in our current allocation proposal.

That portion of the table between 3 and 30 megacycles was then completed by allocating the remaining space to the fixed service. While it is impossible to make a direct comparison between the current proposals for the fixed service and the fixed allocations contained in the Cairo table, since there are so many shared bands in the latter, it is quite apparent that the fixed service will probably suffer a loss in spectrum space in the order of 15 per cent below 10 megacycles, and 5 per cent above that point. It is obvious that when we are faced with the problem of providing spectrum space for new and rapidly expanding services such as, for example, aviation, others must suffer in proportion. In the present United States proposal, while certain other services have suffered somewhat, the fixed service has suffered the most. It is fortunate, however, that the fixed service is in the best position of all the services to take full advantage of the latest techniques in directive antennas for both transmission and reception, selective receivers, strict frequency tolerances, and the use of single sideband and multichannel methods of operation wherever the traffic load justifies. World-wide fixed-service operations cannot possibly operate effectively in this reduced spectrum space unless full advantage is taken of all such modern techniques. This, however, does not lessen the responsibility of each of the other services to utilize modern techniques to the maximum extent practicable.

The preparation of our proposals above 30 megacycles had to be approached on an entirely different basis. Whereas it has never been possible to segregate government from nongovernment operations in the lower spectrum, the principle of such segregation was established above 30 megacycles in the middle 1930's by the provision of exclusive bands for government and nongovernment services. Since this has proven very successful, it was decided to continue its application throughout the upper spectrum.

The spectrum above 100 megacycles was developed and used almost exclusively for military purposes during the war, and for reasons of security classification it was necessary to rely heavily upon the War and Navy Departments for guidance at this stage of our work. As is now well known, radar was one of the most spectacular applications of electronics during the war. This technique had become so useful and was expanded so rapidly that by mid-1942 it became apparent that without some kind of a check, radar equipments in large numbers would soon be in widespread use throughout the upper spectrum to the possible detriment of communications developments. The military services, therefore, found it useful to allocate this spectrum in bands by equipment function, such that certain bands were made available exclusively for radar, certain others for pulse communications, others for conventional communication systems, etc. This proved so successful that it was decided to apply this principle to the postwar allocation problem. It then became necessary to examine all of the radar equipments in existence or in the process of development and decide which should prove most suitable for postwar civil application. This was a difficult task since many assumptions had to be made, but the utter impossibility of providing more than a very limited part of the spectrum for radar use made it imperative. Accordingly, bands were blocked out for radar application at 420 to 460 megacycles, 960 to 1215 megacycles, 1600 to 1700 megacycles, 2700 to 3700 megacycles, 4000 to 4200 megacycles, and 8500 to 10,000 megacycles.

With this done, the amateur bands were placed in the table at various points throughout the upper spectrum, following which certain aeronautical needs were provided for from 108 to 132 megacycles, 328.6 to 335.4 megacycles, and 5000 to 5250 megacycles.

I am sure there is no need to tell what was done to provide for the various forms of broadcasting above 30 megacycles since this has been widely publicized and discussed throughout the industry. In order to complete the record, however, I will state briefly that 13 six-megacycle channels have been provided for television broadcasting between 44 and 216 megacycles, together with an experimental allocation for this service between 480 and 920 megacycles; frequency-modulation broadcasting was provided for between 88 and 108 megacycles, while facsimile broadcasting finds as its spectrum space 470 to 480 megacycles and 106 to 108 megacycles, which latter band is shared with frequency-modulation broadcasting in area 1.

The remaining spectrum between 30 and 30,000 megacycles was divided between government and nongovernment services and labeled "fixed and mobile," or "fixed and mobile except aeronautical mobile," in order to provide the greatest possible flexibility in effecting future frequency assignments.

In making its detailed breakdown of the nongovernment allocations, the Commission has introduced a unique innovation by providing for a new service between 460 and 470 megacycles known as the citizens radio communications service. Herein there is included a portable mobile service for use by the public in the

cities, on the highways and in rural areas, the possibilities of which are as broad as the imagination of the public and the ingenuity of equipment manufacturers can devise. It can be used, for example, to establish a physician's calling service; department stores, dairies, laundries, and other business organizations can use it in communicating to and from their delivery vehicles; it can be used on farms and ranches for communicating to men in the fields, on board harbor and river craft, in mountain and swamp areas, and during emergencies when wire facilities are disrupted. It follows, of course, that common carriers will not be permitted in this band and, therefore, that no charge can be made for the transmission of messages or the use of the licensed facilities in this service.

As we have proceeded with the preparation of our proposals for the next service-allocation table, we have been deeply interested in the progress of similar work by other nations. During the course of the Third Inter-American Radio Conference at Rio de Janeiro, an opportunity was afforded to exchange views with the other American nations. The United Kingdom has made available to us informally certain of their views with respect to this problem, and I am glad to be able to report that there seems to be no insurmountable problems in reconciling such differences as now exist. It is hoped that a limited agenda conference can be held in the near future to exchange views further on frequency allocations and related matters, and possibly to provide a temporary solution to the problem of effecting international frequency registrations.

Many problems, however, remain to be solved before our work has been completed. For example, there have been developed during the war several systems for long-range air and surface navigation, the principal ones being standard loran, low-frequency loran, Decca, consol, P.O.P.I., and gee. The two systems first mentioned, which were developed by the United States, use pulse technique; the others were developed or perfected by the United Kingdom and of these only gee is a pulse system. The Third Commonwealth and Empire Conference on Radio for Civil Aviation, held in London in August, 1945, devoted considerable attention to this subject and attempted to determine which of these should be proposed as a world-wide system for long-range air navigation. While standard loran was so designated by this Conference and later by the Communications Subcommittee of the Air Navigation Committee of the Provisional International Civil Aviation Organization, its very limited usefulness over land indicates that it does not provide a final solution to this problem. Certain elements in the United Kingdom, particularly those concerned with surface navigation, are inclined toward Decca, consol, or P.O.P.I., principally because such systems do not require special receivers and are more economical to operate. The problem is further complicated because there seems to be no hope of a world-wide allocation for low-frequency loran without a serious dislocation of the European broadcast system. A solution to this problem must be found on or before the time of the next conference, since the congestion of the spectrum will not permit a world-wide allocation for more than one such system.

Another point concerning which doubt exists is the proper treatment of the spectrum above 10,500 megacycles. One school of thought indicates that we know too little about it now to attempt service allocations therein and therefore believes that it should be labeled "experimental." Another school of thought argues that even though it is too early to effect precise service allocations, from the research standpoint there should be some general indication of those bands in which pulse techniques should be permitted and those in which they should be excluded.

Pulse-communication techniques are attracting the attention of many engineers at the present time. Assuming that pulse and conventional modulating systems cannot operate effectively in the same band, we must determine in which bands they are to be permitted, and those from which they are to be excluded. Furthermore, before pulse-communication systems are placed in operational use it should be determined whether such systems make sufficiently efficient use of the spectrum, as compared to systems employing conventional modulation, to permit their general use.

Additional points to be determined prior to the conference are the desirability of segregating aeronautical fixed communications in exclusive bands, and the feasibility of attempting an international peak-power limitation in certain parts of the spectrum which are allocated on a regional basis.

It is obvious that if an allocation table similar to the one we have been discussing were adopted by the next world conference, it would be necessary for stations all over the world to be shifted into other service bands, thereby losing the international priorities they have now established. I think it is equally obvious that no nation would be willing to give up the priorities it has established unless all other nations agreed to do likewise. The present International List of Frequencies has become practically useless; it contains many stations which do not now exist, and does not contain many stations established since 1939 which were not registered because of the war.

Looking toward a solution to this problem, the United States now proposes that the next conference should effect the establishment of a permanent International Frequency Registration Board, composed of five members and three alternates to be elected by the conference as custodians of an international public trust, to undertake the task of effecting the international registration of frequencies.

Thereafter, any nation which has begun or proposes to begin the use of a frequency would submit to this Board a notice giving the necessary technical information required. The Board would first determine if the

notice were in conformity with the table and rules for the allocation of frequencies; second, decide if it were in conformity with the other provisions of the convention and regulations; and finally, determine if harmful interference would result to the use of any other frequency previously registered with the Board.

The proposal is predicated upon the principle that the new International List of Frequencies, based upon the official International Frequency List as maintained by the Secretary of the Union, would contain two date columns, one called the registration date and the other the notification date. Each frequency listing, however, would be given a date in only one of the two columns, depending upon the findings of the Board for the case in question.

Generally speaking, a listing would be given a date in the registration column only if it was found to be satisfactory in all three of the particulars named above. The notice would be returned to the notifying government if it was found not to be in conformity with the provisions of the Convention and Regulations (other than the allocation table). In the other cases it would be given a listing with the date in the notification column, with suitable provision for later transfer to the registration column under certain circumstances.

It is obvious that with such an International Frequency List, the existence of a date in its registration column would be taken as prima facie evidence in any negotiations between contracting governments or in any proceedings before the International Court or Board of Arbitrations that the Board had made a finding that the operation in question could take place without causing harmful interference with services rendered by stations for which assignments had previously been registered. No such prima facie evidence would follow from the appearance of a date in the notification column of the list.

In addition to the duties outlined above, the Board would be given certain advisory functions in connection with the selection of substitute frequencies more technically suitable than those notified; the issuance of reports containing its technical findings and recommendations in cases of alleged improper operation or harmful interference; or the making of recommendations to facilitate the more effective use of a particular portion of the spectrum by the accommodation of additional channels or services. It is further proposed that, under certain circumstances, such changes in registrations could be effected, with the consent of the parties concerned, without loss of priority on the part of the existing registrations so affected.

In the earlier stages of our work on this problem we were tempted to give the Board much more power, but after careful consideration it was decided that the nations of the world had not yet advanced to that state where we could, in effect, transfer their sovereign rights to an International Board of this character.

It is quite apparent that this Board could not begin its work with the present International Frequency List in the condition in which we now find it. While we are still considering this aspect of the problem, it is our present belief that it will be necessary for the next conference to appoint a special engineering committee which would have as its only objective the re-examination of the present International Frequency List, in order to remove therefrom all stations which are inactive and to readjust the assignments of the remaining stations in accordance with the service allocation table adopted by that conference and with engineering principles, so as to avoid harmful interference.

One thing demonstrated by the war is the desirability of close liaison between research and development on the one hand, and frequency service allocations on the other. Each is dependent upon the other; the former, to avoid the expenditure of large sums in the development of systems which cannot be accommodated in the spectrum; and the latter, to insure that the allocation table reflects, to the fullest extent possible, the latest advances in the radio art. As a step toward that end, the Commission, in the recent reorganization of its Engineering Department, has placed the Laboratory Division, the Field and Monitoring Division, the Technical Information Division, and the Frequency Service-Allocation Division within the same Branch. It is to be hoped that equally close liaison will develop within the industry, and between industry and government.

Naval Wartime Communication Problems*

J. O. KINERT†

I AM addressing you as a communication officer who had to use the equipment which you and other engineers developed. I would prefer to claim more technical knowledge in addressing this group, and must beg your indulgence as a user rather than as a designer of electronic equipment.

After considerable communication experience in the fleet, I served as communication officer on the staff of the Commander, Third Amphibious Force, from August, 1943, until May, 1945. Since June, 1945, I have been in the plans and operations section of the office of the Chief of Naval Communications.

My purpose is to present a frank appraisal of some of the problems involved in wartime communications and to recommend design principles based on the lessons learned during the recent war. In justice to the splendid support we had from the electronic industry and the many scientific groups in the country, I wish to make clear that our equipment was generally excellent. The amazing quantities of equipment produced, all of which met or exceeded the requirements of the specifications under which it was procured, stand as a record of achievement which is well known to all of you.

Due to the broad scope of my subject and the necessary briefness of its treatment, I will have to resort to the use of statements which are generalities. Such statements indicate conditions which, while to a large degree true, are subject to many exceptions that I have no desire to deny simply because I do not cite them. For example, I may say that our personnel, because of necessity, were not always sufficiently trained without explaining that we did, very fortunately, obtain the services of many excellent engineers, technicians and operators from both amateur and professional sources in civil life.

Communications are so vital in modern war that any failure may result in consequences ranging from inconvenience to the loss of whole campaigns. The potential power of large and complex forces cannot be developed and used against the enemy unless the efforts of all components are co-ordinated. Such co-ordination depends entirely upon reliable, secure, and rapid communications. It was our success in approaching this ideal of co-ordination that made possible our successful amphibious campaigns. We have made much progress since a Persian king tattooed his message on the scalp of his slave, but our very existence, at some future time, may depend to a large extent upon what progress we make in electronic developments.

From the first days after Pearl Harbor, communication traffic increased much faster than our organization and installations could be expended to handle it. We still needed more and better operators, equipment, and frequencies when VJ-Day arrived, but by this time lack of clear frequencies was a more restrictive factor than lack of personnel or equipment.

Normal naval communications which had been the object of much training and planning in peacetime were generally satisfactory. Amphibious communications, on the other hand, presented new problems for which we were, to a great degree, unprepared. In point-to-point work the use of teletype methods and semiautomatic tape relay permitted sufficient expansion of system capacity so that we could handle all traffic offered. This system was extended to key overseas points by use of radio-teletype links, including the adoption of multiplex operation.

When we commenced our amphibious offensive in the Pacific, this type of operation was new to the experience of most of the participants. The marines and a few naval personnel had engaged in amphibious exercises in peacetime, but all had much to learn before they could claim proficiency in this type of operation.

In communications, particularly, the problems of amphibious assault were staggering. Control of naval gunfire, supporting aircraft, and all types of landing craft had to be centralized in a flagship which also acted as an "afloat command post" for the commanding general of the assault troops. This could be accomplished only by improvising additional facilities in whatever type of ships were available. We used battleships, destroyers, and transports until we could design, build, and equip sufficient command-communication ships to do the job properly.

The magnitude of the larger amphibious operations, such as Leyte, Lingayen, and Okinawa, is hard to portray in a few words. Whole series of landings, varying from regimental to two-divisional in force, were carried out simultaneously on a front twenty miles or more long. Hundreds of transports and landing ships and thousands of landing craft were supported by tens of battleships, cruisers, and small carriers, and scores of destroyers, destroyer escorts, submarine chasers, and minesweepers.

After the troops were ashore, gunfire and air support was continued for weeks. In close support of troop operations we were often called upon to deliver shells, bombs, rockets, or machine-gun strafing within a few hundred feet of our front lines. The ordnance or air officer controlling those attacks had to have continuous communication direct to front-line positions, and the attacking ships or planes, in order to insure that the enemy and not our own troops would feel the effects of our attack.

* Decimal classification: R565. Original manuscript received by the Institute, January 24, 1946. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 26, 1946.

† United States Navy Department, Washington, D. C.

Analysis of early actions showed the majority of communication difficulties to be caused by one or another of the following:

(a) *Inexperienced Personnel*

This was our outstanding limitation. We met it by constant training, simplification of duties, and specialization. In many cases an excellent piece of equipment failed to render the performance for which it was built simply because it was manned by an inadequately trained operator. It might seem that the solution should be more careful selection and better training of personnel, but I am convinced that this is only part of the answer. I believe that any future war will find this country placing inadequately trained personnel in the field because we can neither afford the luxury of a sufficiently large professional force to meet all contingencies, nor in an emergency can we insure adequate training and still place the required forces in the field on time. The fact that we were able to maintain effective communications, under conditions where often whole groups arrived in battle for the first time with only a few per cent of their numbers having even peacetime experience in either naval or civilian communications, is a tribute to the intelligence and resourcefulness of the average American. They made some mistakes but they also established an outstanding record of accomplishment. Most American boys have developed mechanical ability through maintaining bicycles, jaloppies, and old alarm clocks, that was a godsend when they were called upon to learn quickly how to operate the complicated mechanisms and devices of modern war.

(b) *Equipment Failures*

Many of these were also incident to inadequately trained personnel. But if we accept the experience of this war, we must accept as a design principle the fact that equipment must be operated and maintained by personnel after the minimum training possible. Exceptions to this principle should be certain delicate and complicated equipment which must produce maximum performance regardless of the difficulty of insuring trained operators and technicians.

(c) *Planning Failures*

Most of these occurred in the early days, but we continued to the last to learn ways to better our plans. We often learned by bitter experience. In addition to our own inexperience and lack of ability to foresee possible developments, certain physical limitations complicated our problems. In the beginning, the most important were shortages of personnel and equipment. Later, the most difficult problem was to crowd all the necessary communications into frequency bands limited both by propagation characteristics and by equipment coverages.

(d) *Enemy Action*

Fortunately, outside of occasional destruction by bombs and other missiles, the Japanese were not in a position to interfere seriously with our communications. They were so short of electronic matériel that they could ill afford to divert much equipment to interfere with our operations. Next time we may have a less impoverished opponent. An example of enemy action occurred at Vella la Vella when air raids destroyed a great deal of our communication and radar equipment on the beaches. Incidentally, the same raids made a foxhole a far safer place for personnel than the top of a hill which was to be the location of the new radio station. In spite of this, Lieutenant Mervin Fickas, who in civilian life was a radio engineer from the West Coast, managed to establish and maintain communications with our Guadalcanal headquarters on a 9-watt portable set over a distance of about 180 miles. This feat enabled us to expedite replacement of ammunition and other stores destroyed by the enemy. In all cases, reverses due to enemy action were met with courage and resourcefulness. The same was not true of the Japanese, who frequently became completely ineffective and disorganized when something interfered with their plans. I suspect that communication failures played a large part in their difficulties under adversity.

Other lessons were:

(a) *Co-ordination of Equipment Design Within and Between All of the Armed Services is Essential.*

This had been foreseen in the last period of peace, but on the principle that the various services would benefit by working primarily on different frequency bands. Most portable equipment was designed to cover a relatively narrow band of frequencies common to all services and a wider band that was not normally covered by equipment of other services. This policy resulted in great overcrowding of the common coverage bands in order to provide the interservice channels of communication required.

(b) *Reliability of Equipment is often Preferable to the Ultimate in Performance.*

In my experience, most of our equipment had adequate performance characteristics to meet operational requirements, provided it operated at all. Some of us were a bit jealous of the Japanese when we found that their equipment, while inefficient and obsolete, was simple to maintain and strongly constructed. However, our equipment was far superior in performance, and usually in reliability, to anything the Japanese had. I am only indicating a willingness to sacrifice performance, in some cases, to reliability. Reliability depends largely on operating conditions and adequate maintenance. Design should reflect the possibility of abuse and unavailability of repair facilities in combat.

(c) *More Efficient Use Must Be Made of Existing Radio-Frequency Channels.*

This problem is particularly acute in the case of frequencies suitable for long-range communication. There are no possibilities of finding new frequencies in these bands; all of them are in use now. It does seem possible to develop new techniques which will permit more intelligence to be transmitted in a given time on a specified frequency band.

To those of you who may, in the future, be engaged in design or development of military equipment, I wish to recommend:

(1) the greatest simplification of operation and maintenance consistent with performance specifications;
(2) reduction of weight and size to the practicable maximum consistent with required resistance to immersion, vibration, etc.;
(3) standardization of parts and components to simplify the supply and use of spare parts in the field;
(4) maximum use of automatic or other design features which may reduce the number or qualification of operating personnel required.

In the first war using modern electronic devices, I attribute a large measure of the credit for our successes to the contributions of our electronic engineers. The armed services have learned many lessons and are now engaged in plans so to strengthen our defenses that we may not become engaged in another war. To implement these plans we must rely on you to provide the skills and inventive genius which will keep us ahead of any other country of the world in the use of electronics.

Address of Retiring President*

WILLIAM L. EVERITT†, FELLOW, I.R.E.

THE YEAR 1945 was a momentous year in the affairs of the world. Those who lived through it will never forget it and future generations will study its historical effects on their own lives. The significance of its events will be determined primarily not by what happened, but by what was started. The United Nations Organization is a plan for the future; the capitulation of our enemies makes that plan an actuality; the atomic bomb marks the beginning of an era whose potentialities are unknown.

In The Institute of Radio Engineers, we may also observe significant beginnings in 1945. The importance of these steps forward lies not in their own completion but in their significance as part of a plan which will lead to a greater and more active Institute. The future will determine whether 1945 provided our organization with the means and the impetus to meet the challenge.

The Institute is a co-operative effort for the advancement of the science and technology of communication, electronics, and the allied arts. It now has over 16,000 members. Co-operation of such a large group can be accomplished only with effective leadership. Your Board of Directors has been active and progressive and it has been a real pleasure to serve as their chairman. But the Directors cannot supply the day-to-day co-ordination necessary in an active organization. They have long realized the necessity of an adequate headquarters staff. I feel that the outstanding advancement of the year has been the development of this staff, and the provision for their adequate housing and support.

Early in the year, George W. Bailey was secured as our executive secretary and the members of the Board have been exceedingly happy about that choice as they have seen him take hold. William H. Crew has joined us as Mr. Bailey's able assistant. The editorial department has been reorganized with the addition of R. D. Rettenmeyer as Technical Editor; Miss Helen M. Stote has advanced to the position of Publications Manager and Miss Winifred Carrière has taken the position of Assistant Editor. Miss Elizabeth Lehmann and her staff have accomplished the unbelievable in the handling of a mountain of correspondence and performing the other office functions. Miss Alice Connolly has reorganized our bookkeeping department. I wish there were time to mention all of our loyal staff and what they have contributed.

Robert Jacques has accepted the position of Technical Secretary, and, at long last, we will have a full-time co-ordinator of our technical committees and other technical activities.

Such a staff deserves the best in accommodations. In 1945, we made that possible. With the energetic leadership of our Building Fund Committee headed by B. E. Shackelford, Ivan S. Coggeshall, and Raymond F. Guy, $625,000 was raised. Not only will this provide an adequate building, but also it will be endowed so that the burden of maintaining it will not exceed the rental of our present inadequate quarters. These funds have been translated into an actual building at Fifth Avenue at 79th Street, in a location where it will be pleasant to work and pleasant for our membership to visit and do business. The selection and purchase of a building seems simple, but let me assure you that the Building Committee, led by Raymond A. Heising and with the able assistance of our attorney, Harold R. Zeamans, overcame

* Decimal classification: R060. Original manuscript received by the Institute, January 29, 1946. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 24, 1946.
† University of Illinois, Urbana, Illinois.

difficulties which at times we feared were insurmountable. I do not see how we could possibly have come out better than we did.

The raising of this building fund has also established close ties with industry under the direction of W. R. G. Baker's subcommittee and with the sections themselves under the leadership of Austin Bailey. It also brought out criticisms of the Institute which have been most helpful. We feel that the value of the Building Fund Campaign in these intangible results was of importance comparable with that of the money raised.

The development of an adequate headquarters staff would have been a precarious and useless undertaking if we had not provided for adequate financing to pay their salaries and engage in the activities they will lead. The membership recognized this and voted to raise their dues by the adoption of the Westman Amendment. It is a unique accomplishment when 83 per cent of the voting membership of any society agree to raise their own dues. It indicates the faith of our membership in the organization and places a great responsibility on our Board to be sure that the money is spent wisely, for the benefit of all.

The most important single activity of the Institute since its inception has been its publications. The PROCEEDINGS, under the editorship of Alfred N. Goldsmith, have been unequalled in their field and unexcelled as examples of high quality in technical society journals. We rejoice that Dr. Goldsmith has been restored in health in order to continue his service to the Institute. The editorial staff, under his leadership, has developed further plans during the year which are now coming to fruition. A new publication, WAVES AND ELECTRONS, appeared in January. It begins as a section of the PROCEEDINGS but we expect that ultimately it will be issued as a separate publication to give greater service to our entire membership.

The YEARBOOK is nearly ready for publication. Dr. Goldsmith and Mr. Copp, our Advertising Manager, are planning a greatly expanded edition, and the work of preparing it has been enormous, in view of our recent growth and the frequent moves of our members. You will be surprised when you see the improvements which have been made. The editorial staff also deserves special commendation for the speed with which it expanded the PROCEEDINGS immediately after V-J Day, when more paper became available.

Next to the publications, the most important contact of the society with its membership is the work of the Sections. I have been fortunate in being able to meet with every Section in the United States and Canada since my election. I can assure you that they are an active group and have the interests of the Institute at heart.

To help the Sections, a speakers' bureau has been organized under the direction of Dr. Crew, to assist in the planning of programs. He is ready to serve you but will need your co-operation and suggestions to develop this program adequately. He is planning a traveling lecture series for the near future.

In order to increase Section activities, provisions for greater financial support were made this year and the continental United States was redistricted so that every member in that area belongs to some section, as shown on the map in the January, 1946, PROCEEDINGS. We hope that the new Section members who are geographically remote from the cities will find some opportunities each year to visit their section and get acquainted with its activities. In turn, the sections must look after the interests of these new men to the same extent as they do their older members. We are awaiting the recommendations of the Canadian Council on the districting of Canadian Sections.

It has not been the policy of the Board to found new Sections by Headquarters action. The initiative must come from local groups so that there may be assurance of interest and leadership. This policy has been proven to be a wise one. I would recommend to members with initiative, who live in urban areas either far removed from present sections, or where there has developed increased interest in our field, that they contact Headquarters and get lists of members in their locality who could serve as a nucleus for a Section. They will find that Headquarters is now organized to give them aid. They can do the Institute and themselves a real service by organizing. It has been a common experience that when a Section is once initiated, the local membership grows manyfold. Several Subsections were developed during the year and the Sections Committee has made recommendations.

Our membership in countries outside the United States and Canada has now grown so that, with the coming of peace, a number of other groups throughout the world are following the lead of our members in Argentina and are planning Sections. It is to be hoped that this evidence of healthy growth will be accelerated.

With the development of an adequate headquarters staff, the Board of Directors should and will function less in guiding operations and more in determining policy. This determination of policy should be guided by the entire membership. To make this effective we need:

1. A larger proportion of our membership in the voting-professional grades.
2. Regional representation on the Board of Directors.

Steps to fulfill both these needs were taken this year but they require further action by the membership.

The individual Sections were asked to set up personnel committees to accelerate transfers of qualified personnel into the Member and Senior Member grades. A simplified procedure for providing reference information was developed and transmitted to the Sections. As a result, 722 members were transferred to higher grades in 1945, compared with 324 in 1944, and 525 were admitted to higher grades, compared with 157 in 1944. The admissions to the Associate grade were about 1800 each

year. This represented an enormous task for the Admissions Committee led by G. T. Royden. They have worked long and hard, are frequently scolded by the members, but seldom appreciated. I want to express publicly the appreciation of the Board for their work. To clarify their method of operation to the members, they have prepared a detailed Manual of Operations which has been sent to each Section for their guidance.

There are still many professional radio engineers in the Associate grade and it is important that those who can qualify, advance, obtain voting privileges, and participate in directing the affairs of the Institute.

A special committee under the chairmanship of Harold Wheeler has prepared a plan for the election of regional representatives to the Board of Directors and for the maintenance of regional committees to handle problems of local interest. This plan was referred to the Sections for advice and many helpful suggestions were received. The Constitution and Laws Committee has drafted a constitutional amendment to activate the plan. You will get full details and a ballot shortly. I strongly urge the adoption of this amendment as a forward step in Institute management.

The technical committees of the Institute have not been very active during the war, largely due to factors beyond their control. As a result there is an enormous backlog of work to be done. This work can be accomplished only by our individual members. We confidently anticipate that the selection of a Technical Secretary will provide the necessary co-ordination that only full-time leadership can give. The standing of our Institute with industry and with other societies will depend largely on the accomplishments of these groups. We need to initiate a number of technical conferences for groups of special interest. The time for action in this field is here. Let's get going.

Engineering, like religion, is broken up into many groups. As a result, the voice of the engineer frequently cannot be heard in the councils of state and of industry because it is a babble instead of a voice. The ultimate solution for this must lie in an over-all engineering organization uniting all engineering societies on matters of common interest, but allowing them autonomy in their special fields. The immediate action to be taken is to initiate closer co-ordination with other societies in the solution of mutual problems. Several steps along this line were taken during the year. Among them were the following:

1. Co-operation through the Radio Technical Planning Board was continued with other societies. Haraden Pratt was elected Chairman and William H. Crew, Secretary of this Board.

2. A co-ordination committee has worked out mutual plans for co-operation with the Radio Manufacturers Association.

3. Joint committees on electronic standards have been set up with the American Institute of Electrical Engineers.

4. A joint plan of co-operation with the British Institution of Electrical Engineers has been developed.

5. A committee on a code of ethics has been co-ordinating with the Engineers Council on Professional Development.

6. A plan for the development of joint student branches with the AIEE has been initiated.

7. A conference of presidents of leading engineering societies was called at the invitation of your president to consider the problem of the resumption of the training of engineers in the universities. A program and resolution were prepared, subsequently adopted by the great majority of societies represented, and are now being presented to the Congress and the President.

8. All co-ordinated activities with groups such as the American Standards Association, the American Association for Advancement of Science, and others, have been continued.

Only the highlights of a busy year have been presented. When the servant of Andrew Jackson was asked after Jackson's death if he thought Old Hickory had gone to Heaven, he replied, "I don't know, suh, but if he wanted to get there, he'll get there."

The year 1945 was a year of preparation—1946 should be a year of accomplishment. If you set your goal high and want to get there, you'll get there, and soon. You have selected an energetic and able new leader. It gave me great pleasure to serve you. It gives me even greater pleasure to turn over the reins of office to Frederick B. Llewellyn.

Final Report of the National Patent Planning Commission*†

THE National Patent Planning Commission consisting of Charles F. Kettering, Chester C. Davis, Francis P. Gaines, Edward F. McGrady, Owen D. Young, Andrey A. Potter, and Conway P. Coe made a final report on their activities. The Commission left unfinished the study of various problems but presumably these will be considered by an equivalent commission appointed by President Truman on April 20.

In the final report the Commission emphatically reemphasized that the suggestions offered by the Commission in the first report did not include any changes which departed from the basic principles of the patent system. The Commission again pointed out that the principles of the patent system are sound and therefore the Commission has rejected any proposals for revision of the patent system involving a departure from the principles upon which it was founded and by the effectuation of which it has furthered the nation's industrial and social improvement.

The principal suggestions for improving the patent system without departing from its principles included:

(1) a single court of patent appeals;

(2) Congressional establishment of a reasonably understandable test of patentability;

(3) reference back to the Patent Office of technical questions raised in infringement suits for advisory opinion as to the validity of the patents involved;

(4) recording of all contracts relating to patents;

(5) a twenty-year term for patents beginning with the filing date;

(6) simplification of appellate procedure;

(7) challenge of validity of a patent within six months of the date on which it is granted;

(8) limiting the recovery of the patent owner to reasonable compensation without prohibiting the continued use of the patented invention in the fields of National Defense, public health, and public safety;

(9) creation of a public register for owners of patents willing to license others at a reasonable royalty;

(10) rejection of all proposals for general compulsory licensing of patents.

With respect to the last recommendation the final report again emphasizes that compulsory licensing would not only nullify the patent owner's proprietorship, but would also discourage inventiveness and lessen the initiative of investors by exposing them to greater uncertainty and larger risks in the investment of capital requisite to the development and commercialization of new mechanisms and compositions. The report also emphasizes that the property represented in the patent is unique and that the invention safeguarded thereby has been brought from the realm of ideality to the sphere of actuality and utility. Except for the inventor's success in converting mere potentiality to materiality, the world would have been deprived of a benefit whether great or small; whether a telephone, an airplane, a radio, or a useful but simple latchet for a shoe.

* Decimal classification: 347.7. Original manuscript received by the Institute, October 18, 1945.

† This summarized account was prepared for The Institute of Radio Engineers by Alois W. Graf, (Senior Member, I.R.E.) former Secretary of the Chicago Section.

Proposed Standards of the Radio Manufacturers Association*

Introduction

IN furtherance of the joint program of The Institute of Radio Engineers and the Radio Manufacturers Association for closer collaboration in standardization activities, and to keep I.R.E. members informed on such matters, the Institute will from time to time publish RMA Standards and Standards Proposals of general interest.

RMA Standards Proposals are submitted to members of the RMA after they have been approved by the Executive Committee of the originating section. Although they do not become RMA Standards until they have been approved by the RMA membership, and in some cases require modification before acceptance, it is considered that a useful purpose is served in publishing them in advance of formal adoption. A group of such RMA Standards Proposals follows:

* Decimal classification: R020. Original manuscript received by the Institute, January 11, 1946.

No. 163—Very-High-Frequency Broadcast Receivers; Intermediate Frequency

The intermediate frequency for very-high-frequency broadcast receivers shall be 10.7 megacycles.

No. 164—Television Broadcast Receivers; Antenna-to-Set Transmission Line

The antenna-to-set transmission line for television broadcast receivers shall be an unshielded, parallel line of 300 ohms impedance.

No. 165—Television Broadcast Receivers; Intermediate Frequency for Sound Channel

The sound-channel intermediate frequency of television broadcast receivers shall be located in the region 21.25 to 21.9 megacycles, and the oscillator frequency shall be higher than the signal frequency, thus placing the corresponding upper-frequency limits of the video channel between 26.5 and 27.15 megacycles.

No. 166—Export Receivers

166-1—Stating the Number of Tubes in Radio Receivers.

It shall be standard in stating the number of tubes in a radio receiver to state the total number of evacuated envelopes, exclusive of such of these as provide enclosure solely for illuminants.

166-2—Specifying the Frequency Coverage of Broadcast Receivers.

It shall be standard to state the assured upper- and lower-frequency limits of all continuous frequency bands in terms of:

(a) Kilocycles, where the lower limit of frequency is less than two megacycles.

(b) Megacycles, where the lower limit of frequency is between one megacycle and one kilomegacycle.

(c) Kilomegacycles, where the lower limit of frequency is between one kilomegacycle and one megamegacycle.

166-3—Specifying the Power-Supply Voltage and Power-Supply Frequency of Broadcast Receivers.

It shall be standard to specify the values or range(s) of voltage and the value or range of frequency of the power supply on which satisfactory operation of the receiver is assured. (For example: 90 to 130 volts; 180 to 260 volts; 50/60 cycles.)

No. 167—Chassis Pickup in Vehicular Receivers

It is proposed that vehicular receivers shall be considered as complying with the principles of good engineering practice if, when installed according to the manufacturers' instructions and using materials supplied by the manufacturer, there is no *perceptible chassis pickup* with any setting of the user controls.

"Chassis pickup" is defined as the interference arriving in the vehicular receiver other than through the antenna.

"Perceptible" is defined as the difference in the noise output of the receiver with the engine running and with it stopped.

Testing for chassis pickup shall be done by replacing the antenna of the installed receiver by an antenna equivalent, adequately shielded and grounded; the antenna trimmer of the receiver shall be tuned for resonance at the normal aligning frequencies; and observation made of any perceptible noise output.

No. 168—Type Designations for Electron Tubes

It is proposed to rescind the type-designation system for transmitting and special-purpose tube types here shown and identified by number SP 168-1, and simultaneously to standardize the proposed numerical system of type designation for other than receiving-tube types and cathode-ray-tube types here shown and identified by number SP 168-2.

SP 168-1—It is Proposed that the Following Scheme of Type Designation be Rescinded

For transmitting and special purpose tubes: the type designation shall comprise three distinctive symbols. These will be, in their regular order, a number symbol, a letter symbol, and a number symbol, the significances of which are given below:

1. *The first number symbol* will indicate the cathode power required for normal operation in accordance with Table I.

TABLE I

Designation	Range of Filament or Heater Power	Watts
1		0
2	In excess of zero watts and up to and including	10
3	In excess of 10 watts and up to and including	20
4	In excess of 20 watts and up to and including	50
5	In excess of 50 watts and up to and including	100
6	In excess of 100 watts and up to and including	200
7	In excess of 200 watts and up to and including	500
8	In excess of 500 watts and up to and including	1000
9	In excess of 1000 watts	

2. *The letter symbol* will indicate the structure in accordance with Table II.

TABLE II

A. Monodes—Such as ballast tubes and vacuum-sealed resistors.
B. Diodes—Including full-wave as well as half-wave rectifiers, protective tubes, spark gaps, voltage regulators, etc.
C. Triodes—Including thyratrons, cold-cathode three-electrode control tubes, etc.
D. Tetrodes—Including thyratrons, cold-cathode four-electrode control tubes, etc.
E. Pentodes
F. Hexodes
G. Heptodes
H. Octodes
L. Vacuum-sealed types of capacitors
N. Crystal detectors and crystal rectifiers
P. Photo-emissive, vacuum-sealed devices; phototubes, photomultipliers, pickup tubes, etc.
R. Mercury-pool types, inclusive
S. Vacuum-sealed contactor-type switches

3. *The second number symbol* will be a serial designation and in no case shall be less than 21.

Use of Suffix Letter for Type Designations

(Standards Proposal No. 144)

It shall be standard to use the same type designation for both the prototype and the improved version where complete interchangeability exists between the two types, and to assign different type designations in accordance with the appropriate standard to tube types that are not completely interchangeable, except that it shall be standard to permit the assignment of a suffix letter in alphabetical order, beginning with *A*, to the

type designation of a prototype to identify the improved version where both

A. unilateral interchangeability exists between the improved version and the prototype; i.e., where the improved version may serve to replace the prototype in all known, important applications but not vice-versa, and,

B. the improved version is intended to displace completely the prototype.

Typical Type Designations

1C23	3C44
1N35	6D25
2C53	1P39

SP 168-2—It is Proposed that the Following Scheme of Type Designation be Adopted

I. It shall be standard to use the following system of type designations for tubes and devices exclusive of receiving and cathode-ray tubes.

II. The type designation shall consist of a pure numeric starting with 5500 and shall be assigned consecutively and chronologically in the order of type-number request.

(The request shall be accompanied with sufficient data to define the tube adequately.)

III. A new type designation shall be assigned to a new version of a prototype whenever the new version is not completely interchangeable with the prototype.

(Whenever a new designation is assigned to a type which is unilaterally interchangeable with a former type, such interchangeability may be indicated by marking the new type with its assigned designation followed, at the option of the manufacturer, by the designation of the former type.)

This system shall not be retroactive.

Typical Type Designations

5501	5923
5712	6234
6545	

No. 169—Proposed Dimensional Characteristics of Phonograph Records for Home Use.

	10 inch Records	*12 inch Records*
169.1—Diameter	$9\frac{7}{8}''$ $\pm\frac{1}{32}''$	$11\frac{7}{8}''$ $\pm\frac{1}{32}''$
169.2—Thickness Measured at 4 points, 1 inch from outer edge, 90 degrees apart	$0.080''\pm0.010''$	$0.090''\pm0.010''$
169.3—Diameter of outermost groove of recording pitch	$9\frac{1}{2}''$ $\pm0.02''$	$11\frac{1}{2}''$ $\pm0.02''$
169.4—Center-hole diameter	$0.286''{}^{+0.001''}_{-0.002''}$	
169.5—Minimum inside diameter of recording	$3\frac{3}{4}''$	
169.6—Eccentric stopping groove		
(a) Diameter	$3\frac{3}{8}''$	
(b) Run-out relative center hole	$0.250''\pm0.015''$	
(c) Groove shape		
(1) Minimum depth	$0.003''$	
(2) Contour approximately as music grooves.		
169.7—Concentricity of music grooves Indicated run-out relative center hole	$0.020''$ (maximum)	

169.8—Lead-in spiral
At least one complete turn between outer edge of record and recording pitch.

169.9—Lead-out spiral
Nominal pitch $\frac{1}{8}''$ (minimum)
Contour: approximately as music groove.
Depth: may vary to blend from music groove to eccentric stopping groove.

169.10—Shape of outer edge.
(a) Semicircular, or
(b) "V"
Where "V" edge is used, it is recommended that it have
(1) Included angle of 80 degrees $\pm$ 10 degrees
(2) Edge radius of $\frac{1}{64}$ inch (approximate)
(3) Apex of the "V" depart from the midplane between record faces by not more than 0.010 inch.

Contributors to Waves and Electrons Section

William L. Everitt

William L. Everitt (A'25–M'29–F'38) received the E.E. degree from Cornell University in 1922, the M.S. degree from the University of Michigan in 1926, and the Ph.D. degree from Ohio State University in 1933. He has taught electrical engineering at Cornell, Michigan, Ohio State, and the University of Illinois. Since 1942, Dr. Everitt has been Director of Operational Research Staff with the Signal Corps of the United States Army and is now head of the electrical engineering department of the University of Illinois. Dr. Everitt initiated and directed the annual Broadcast Engineering Conference at Ohio State. He is a Fellow of the American Institute of Electrical Engineers and a member of Tau Beta Pi, Sigma Xi, Eta Kappa Nu, the Acoustical Society of America, and the American Association for Advancement of Science.

Alois W. Graf

J. O. KINERT

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Alois W. Graf (A'26–M'44–SM'45) was born at Mankato, Minnesota, in 1901. He received the B.S. degree in electrical engineering from the University of Minnesota in 1926, and the LL.B. degree from National Law University in 1931.

In 1926, he entered the United States Patent Office as an examiner of radio, carrier current, and multiplex communication systems, and radio controlled devices. In 1930, he was engaged in patent work in radio and audio systems. From 1930 to 1938, he was a member of the Patent Department of General Electric Company where he handled transmitting, receiving, aeronautic and marine radio applications, and power applications of vacuum tubes.

During 1939 and 1940 he was the patent lawyer for Productive Inventions, Incorporated, and The Anderson Company, both of Gary, Indiana. In 1940, he opened his own patent law practice, and since 1943 he has been associated with Moore, Olson & Trexler, Patent Lawyers, of Chicago, Illinois, specializing in radio, electronic, and electrical patent matters.

He became a member of the bars of District of Columbia in 1931, Indiana in 1940, and Illinois in 1942. He is also a member of the American Bar Association, Chicago Patent Law Association, Chicago Law Institute, Illinois Society of Engineers, National Society of Professional Engineers, and American Arbitration Association.

Mr. Graf's Institute activities include Chicago Section Membership Committee, chairman 1943–1944; Membership Committee, 1944, 1945; Education Committee 1945; Board of Editors 1945; secretary, Chicago Section, 1944–1945; and vice-chairman 1945–1946.

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J. O. Kinert was born on July 25, 1907, at Colfax, Indiana. He graduated from the United States Naval Academy in 1930, commissioned as Ensign. From 1930 to 1936 he served on cruisers and destroyers on the West Coast, and from 1936 to 1938 he attended the postgraduate school of Applied Communications.

After serving in the Asiatic fleet from 1938 to 1941, and on the U.S.S. *Maryland* from 1941 to 1942, he joined the staff of Battle Division Four in 1942, serving in that division until 1943, when he was transferred to the staff of Carrier Division Twenty-two, and later to the Third Amphibious force during the Solomons and Philippine campaigns from 1943 to 1945. He is at present stationed in Washington, D. C., with the rank of Captain, as assistant chief of Naval Communications for Plans and Operations, with the United States Navy Department.

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Paul D. Miles was graduated from the United States Naval Academy in 1927. He resigned his commission in 1929, and became a member of the Naval Reserve. From 1929 to 1936, he was associated with the Mackay Radio and Telegraph Company, and was appointed superintendent of communications, western division, for the Hearst Radio, Inc., in 1936.

In 1939, Commander Miles accepted an appointment as civilian radio engineer in the radio liaison division, Office of Naval Operations, and was ordered to active duty in June, 1941. In 1942, he was transferred to the Office of Naval Communications to handle frequency procurement and assignment activities, and became chief of the frequency section.

Returning to inactive duty in November, 1945, he was chief of the frequency service-

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PAUL A. PORTER

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PAUL D. MILES

allocation division. He became a member of the Interdepartmental Radio Advisory Committee in 1942, serving as vice-chairman in 1943 and chairman in 1944. He is now the Federal Communications Commission member of that committee.

Commander Miles acted as an observer at the Third Commonwealth and Empire Conference on Radio for Civil Aviation, held in London in July, 1945; and served as a delegate to the Third Inter-American Radio Conference at Rio de Janeiro in September, 1945, and to the United States and British Commonwealth Communications Conference, held in Bermuda in November, 1945.

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Paul A. Porter was born at Joplin, Missouri, on October 6, 1904. He was graduated from the University of Kentucky Law School in 1928, and practiced law until 1929 in Kentucky. From 1929 through 1932, he was editor of the Mangum, Oklahoma, *Daily News*, and the LaGrange, Georgia, *News*.

In 1933 Mr. Porter became executive assistant to the Administrator of the Agricultural Adjustment Administration, and from 1937 to 1942, he was Washington counsel for the Columbia Broadcasting System. He was appointed deputy administrator of the Office of Price Administration in charge of organizing the rent-control program in 1942, becoming associate administrator of the War Food Administration in 1943, and in the same year was appointed assistant to the director of the Office of Economic Stabilization.

Mr. Porter served as director of publicity for the Democratic National Committee in 1944, and was appointed chairman of the Federal Communications Commission in December, 1944. Early in 1946 he became chairman of the Office of Price Administration.

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Institute News and Radio Notes

Board of Directors

February 6 Meeting: At the regular meeting of the Board of Directors, which was held on February 6, 1946, the following were present: F. B. Llewellyn, president; G. W. Bailey, executive secretary; S. L. Bailey, W. H. Crew, assistant secretary; Alfred N. Goldsmith, editor; V. M. Graham, R. F. Guy, Keith Henney, L. C. F. Horle, F. R. Lack, G. T. Royden, D. B. Sinclair, H. M. Turner, W. L. Webb, and W. C. White. Guests: P. Dunsheath, president, British Institute of Electrical Engineers; W. K. Brasher, secretary, British Institute of Electrical Engineers; and F. S. Barton, British Air Commission.

President Llewellyn officially welcomed President Dunsheath and Secretary Brasher of the Institution of Electrical Engineers of London, England, and Dr. F. S. Barton of the British Air Commission. He stated that arrangements had been made by the Secretaries of the two societies to learn the names of members of the I.E.E. who plan to visit New York, so that The Institute of Radio Engineers could make arrangements for them to visit Section and technical meetings wherever possible and that the same procedure was being followed with reference to I.R.E. members going to England.

At the request of President Llewellyn, Executive Secretary Bailey outlined the arrangements which had been made with the I.E.E. for each society to handle membership dues and magazine subscriptions for the other society, payment to be made in currency of the country where the subscription was placed and a credit balance to be paid by one society to the other at intervals.

President Llewellyn then called upon Secretary Brasher who stated that he would be happy to put any American member of I.R.E. in contact with the I.E.E. Section representative in London and that he would be pleased to refer such a member to any Section representative of the I.E.E. in other parts of Great Britain where meetings might be held or even for business introductions.

President Llewellyn introduced President Dunsheath who thanked the Directors for welcoming him and Secretary Brasher and Dr. Barton so cordially and for giving them the opportunity to meet the Board of Directors. He stated that correspondence had already taken place between Mr. Bailey and Mr. Brasher with reference to a representative of the I.R.E. participating in their meeting in London in March. He emphasized the wish of the British Council that the British meeting should have a representative of the Institute to enter into the discussions at the London meeting and he stressed the welcome that the representative of the Institute would receive if the I.R.E. would accept the invitation to send a representative to the London meeting.

Secretary Brasher then stated that he hoped the I.R.E. would be able to name at once a representative to come to England as Secretary Brasher would like to secure an adequate place on the program for him. This representative would take part in the opening meeting, which will be under the chairmanship of President Dunsheath, and attended by leading people from all the Services of His Majesty. The First Sea Lord of the British Navy will attend the opening meeting and the equivalent in rank from the Army and the Scientific Government Branches also will attend. The work of the engineer in the development of science and the efforts and co-operation of American scientists in the successful prosecution of the war will be stressed. British engineers and scientists made many scientific and technical developments and many have been developed here in America and it is fitting that the representative of the Institute describe them in Britain. Secretary Brasher also stated that if it was desired he would arrange again to set up the transatlantic telephone link and hold a meeting at a time when it would be convenient and possible for the I.R.E. to have a meeting in New York simultaneously and discuss one of the papers.

Secretary Brasher assured the I.R.E. that the Finance Committee of the I.E.E. would gladly accept the privilege of offering hospitality to any guest from the I.R.E. at the London meeting. He also called attention to the fact that the work of the Liaison Committees of the two societies would be improved if there could be a representative of the I.R.E. who lived in London. When matters are under discussion on either side of the Atlantic it would be helpful to have an I.R.E. representative in England to discuss them, with full power to act under the authority of the Executive Committee and the Council. They would like to have a representative who would be familiar with the reasons for making certain suggestions and with a knowledge of exactly what was under discussion and in reporting back to America.

President Llewellyn then requested President Dunsheath upon his return to extend the greetings of our Board of Directors to the Institution of Electrical Engineers and express our appreciation of their co-operation. In reply President Dunsheath stated he would be delighted to take such a message back to the Council and said that he was sure they would be glad to know the extent to which I.R.E. encourage co-operation between the Institutes.

I.R.E. Representative: President Llewellyn was selected to represent the Institute at the Meeting of the British Institution of Electrical Engineers to be held March 26, 27, and 28, 1946, in London, England.

Approval of Executive Committee Actions: The actions of the Executive Committee taken at its January 9, 1946 meeting were unanimously approved.

Heising Resolution: The Board of Directors expressed their appreciation of the work of Raymond A. Heising in the following resolution:

"On the occasion of the relinquishment by Raymond A. Heising of the Office of Treasurer of the Institute, the Board of Directors expresses to him

—its deep gratitude and that of the membership of the Institute for his devoted and capable services during his long term of office;

—its appreciation of his combination of keen analysis, thorough and consistent accomplishment, and unfailing good nature in his official activities and in his contacts with his associates; and

—its warm wishes for his continued success and health, as well as his future close association in the activities of the Institute."

Constitution and Laws

Regional-Representation Plan: The Board adopted the proposed Constitutional changes, a necessary part of the Regional-Representation Plan, and the proposed Constitutional Amendments will be submitted to the membership for voting.

Article VI, Section 4, Paragraph 1: The Board adopted the proposed modification of Article VI, Section 4, Paragraph 1 which will be submitted to the membership for voting as follows:

"SECTION 4—The Secretary shall be responsible for the preparation for all meetings of the Board of Directors and all principal meetings of the Institute and the recording of the Minutes of such meetings. He shall be responsible for the correspondence of the Institute and the keeping of full records thereof and shall be responsible for the provision of such information from them as is requested by the Board of Directors."

Article VI, Section 5: Article VI, Section 5, was modified for submission to the membership for voting as follows:

"SECTION 5—The Treasurer, under the control of the Board of Directors, shall have general supervision of the fiscal affairs of the Institute and shall be responsible for the keeping of the books of account."

Readmission of Former Members: The board adopted the following resolution:

"RESOLVED, that the Board of Directors readmit to the grade of membership previously held (or the Associate grade if formerly a Junior) those former members (a) whose memberships terminated before or during 1945 and who pay either current dues or all dues in arrears, or (b) whose memberships terminate on April 30, 1946, and who pay dues for 1946 at a later date during 1946. The payment of a new entrance fee, if such would normally be required, is waived. Associates, who formerly had the privilege of voting, will be readmitted as nonvoting Associates."

Committees

Education: The Education Committee was authorized to proceed with the preparation of a plan for joint Student participation in I.R.E.-A.I.E.E. Student Branches.

Liaison: The Board adopted the recommendation of the Executive Committee that E. M. Deloraine be appointed a member of the Liaison Committee; that an American member of the Institute now residing in England be added as a member to the Committee; and that the name of the Committee be changed to "International Liaison Committee."

Proceedings

Board of Editors: The Board of Editors has held two meetings since the close of the war. Editor Goldsmith solicited comments and criticisms from the Board members relative to the journals of the Institute with the assurance that any comments will receive close attention.

An Editorial Executive Committee of five men has been appointed and its functions shall include advising the Editor and the Editorial Department and, when required, interpreting policy and procedures to the Editorial Department. The members of the Editorial Executive Committee will be alphabetically listed and, in the event of the unavailability of the Editor, and when the Editorial Department requires guidance, it will consecutively call the members of the Editorial Executive Committee to obtain guidance. The Editorial Executive Committee will meet more frequently than the Board of Editors and will submit recommendations and reports to the Board of Editors from time to time. A number of new members have been added to the Board of Editors for the purpose of reducing the amount of work to be done by each. The Papers Review Committee and the Papers Procurement Committee have become subcommittees of the Board of Editors.

Postwar Publication Fund: The Board adopted the recommendation of the Executive Committee that $10,000 of the Postwar Publication Fund be released for use during the year of 1946, in accordance with the plan by which the Fund was set up.

Houston and Milwaukee Sections: The Board adopted the recommendation of the Executive Committee that the petitions for the establishment of a Houston Section and a Milwaukee Section be approved.

Veteran Wireless Operators Association: It was unanimously approved that the Board express appreciation to the Veteran Wireless Operators Association for the plaque to be presented to the I.R.E. in recognition of the services of engineers in the war.

Executive Committee

February 5 Meeting: The Executive Committee meeting, held on February 5, 1946, was attended by F. B. Llewellyn, president; G. W. Bailey, executive secretary; S. L. Bailey, W. H. Crew, assistant secretary; Alfred N. Goldsmith, editor; R. F. Guy, Keith Henney, and W. C. White.

A.A.A.S. Bulletin: Dr. Goldsmith called the attention of the Committee to an article, written by Dr. W. H. Crew, regarding the Institute, which had appeared in the January issue of the *A.A.A.S. Bulletin*, and complimented Dr. Crew on the manner in which he had covered concisely the history, purpose, membership details, and aims of the Institute. Mr. Henney moved that appreciation be expressed to Dr. Crew on the preparation of this article.

Electron-Tube Committee: A preliminary report of the Electron-Tube Committee, received from Chairman Guy of the Standards Committee, will be published in Waves and Electrons Section of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS.

Membership: Approval was given to the 358 applications for membership in The Institute listed on page 40 A of the March, 1946, issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS. These applications are as follows:

For Transfer to Senior Member Grade	15
For Admission to Senior Member Grade	9
For Transfer to Member Grade	24
For Admission to Member Grade	47
For Admission to Associate Grade	189
For Admission to Student Grade	74
	358

1947 Winter Technical Meeting: President Llewellyn reported that he had authorized the 1946 Winter Technical Meeting Committee to make tentative arrangements at three different locations in New York, and for two separate weeks for the 1947 meeting.

1946 Electronics Conference: Mr. S. L. Bailey reported that it was the sense of the Electronics Committee meeting held during the Winter Technical Meeting that the Electronics Conference should be held in 1946.

Thompson Memorial: It was unanimously approved that the first Browder J. Thompson Memorial Award be made at the proposed Electronic Conference to be held this summer, subject to approval by Dr. R. R. Law.

During the 1946 Winter Technical Meeting of the Institute of Radio Engineers, the President of the National Academy of Sciences addressed the annual I.R.E. Banquet, held on Thursday night, January 24, 1946. His subject, Industrial Research, is outlined briefly below.—*The Editor*

Industrial Research—Past and Prospective Future

F. B. JEWETT

A brief recital was presented of the status of scientific and technical development activities at the end of the nineteenth century, and of the factors which initiated the beginnings of industrial research in the form with which we are now familiar.

There were then discussed some of the early problems encountered in selling the basic idea, the difficulties encountered in fitting it effectively into the existing industrial structures, problems encountered in finding qualified men, and steps taken in influencing the form of education and in interesting young men to take advanced training in basic science with a view to entering industry.

The early problems of effective organization and those of indoctrinating men with the idea of teamwork were then treated. This was followed by a summary of the influence of industrial research on the organization and operation of other parts of industry.

Tribute was paid to the rapid growth of industrial-research organizations in a wide and expanding sector of industry following World War I and to the powerful position in which the Nation was placed thereby to cope with the problems of World War II.

Looking to the future, there were discussed some prospects for enlargement and change in industrial research resulting from the war experience, the further development of electronics, chemistry, metallurgy, and applied biology.

Some observations were presented on the reaction of these factors on scientific and technical education and on the whole matter of proper Governmental support and control of scientific development.

Fellow Awards

At the I.R.E. Banquet, held Thursday night, January 24, the annual Fellow Awards were presented. Dr. Julius A. Stratton of the Research Laboratory of Electronics, Massachusetts Institute of Technology, accepted the Awards in behalf of the recipients. His speech of acceptance is as follows:

"Mr. President, Members oft he Institute of Radio Engineers, and our guests:

"I am extremely proud to respond in behalf of the new Fellows and to express our appreciation of the honor that has been conferred through this award by The Institute of Radio Engineers. In return, I am sure that for their part it will be the constant endeavor of the Fellows to continue to merit such an honor through unremitting service to the field of radio engineering."

Journal I.E.E.

The ordinary subscription rate of Part III of the Journal of The Institution of Electrical Engineers will be increased from £1 1s. 0d. to £1 11s. 6d., less 50 per cent, which amounts to a change from 10s. 6d. to 15s. 9d. To subscribers taking all three Parts, the rate of £1, 11s. 6d. will remain unchanged.

I.R.E.—U.R.S.I. Meeting

The annual joint meeting of the American Section, International Scientific Radio Union, and the Washington Section, Institute of Radio Engineers, which before the war was held in Washington each spring, is being renewed this year. The meeting will be held in Washington in the Auditorium of the New Interior Department Building, C Street between 18 and 19 Streets, beginning on Thursday, May 2, and will be either a two- or three-day meeting. The program will, as usual, be devoted to the more fundamental and scientific aspects of radio and electronics. It is expected that much material hitherto classified will be released for presentation, and therefore this meeting should be of particular interest. The program of titles and abstracts will be available in booklet form for distribution before the meeting. Correspondence should be addressed to the Institute office, or to Dr. J. H. Dellinger, National Bureau of Standards, Washington 25, D. C.

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I.R.E. Electron-Tube Conference

An Electron-Tube Conference is being planned for June, 1946, by the Electron-Tube-Conference Committee which functions as a subcommittee of the Technical Committee on Electron Tubes. These meetings are limited in scope to the more-fundamental problems connected with the physics of electron tubes and provide a forum for the exchange of ideas between electron-tube specialists with the minimum amount of formality. The subject matter of this conference (the fourth of the series which was interrupted by the war) will be limited to problems of electron dynamics with particular emphasis on these problems as they are encountered in microwave tubes. The Committee is currently distributing a questionnaire regarding the conference to individuals known to be interested in this field soliciting material for presentation and discussion.

Because of the specialized nature of the conference and the size of available facilities, the attendance necessarily must be limited to those actively engaged in work in the field covered by the conference. The Committee, is, of course, extremely anxious that no one be excluded who has a good reason for wishing to attend. Electron-tube specialists who feel that they can contribute to the success of the conference and who failed to receive the Committee's questionnaire are urged to write the chairman at their earliest convenience. Please give your company or institution affiliation, your field of specialization, and a list of subjects on which you can present material or on which you can contribute to the discussion. Further information as to the exact time and place of the conference and the subjects finally chosen for discussion, together with a registration form will be mailed directly to those individuals who have indicated their desire to attend.

Meetings of Standing Committees I.R.E.

Education

Date.....November 1, 1945
Place.....McGraw-Hill Building, New York City
Chairman.....A. B. Bronwell
Acting Secretary...W. H. Crew

Present

A. B. Bronwell, *Chairman*

H. A. Chinn	W. J. Seeley
Alan Hazeltine	R. F. Stansel
G. B. Hoadley	J. A. Stratton
F. H. Kirkpatrick	G. R. Town
H. J. Reich	E. Weber

I. Wolff

Guests

W. H. Crew, *Acting Secretary*

G. W. Bailey	Alfred N. Goldsmith

F. B. Llewellyn

The purpose of this meeting was to discuss plans for the establishment of a Speaker's Bureau, Traveling-Lecture Series, the procurement of symposium papers, and Joint A.I.E.E.-I.R.E. Student activities. There were also considered the shortage of highly qualified young electrical engineers, and the urgency of encouraging veterans to continue their professional education.

Meetings of Technical Committees I.R.E.

Antennas

Date.....October 19, 1945
Place.....Editorial Department, I.R.E., New York City
Chairman....P. S. Carter

Present

P. S. Carter, *Chairman*

W. S. Duttera	D. C. Ports
D. W. Epstein	S. A. Schelkunoff
Sidney Frankel	J. C. Schelleng
R. F. Guy	George Sinclair
E. C. Jordan	P. H. Smith

L. C. Van Atta

The purpose of this meeting was to organize the work of the committee, form subcommittees, and make assignments to them. The following subcommittees were formed to prepare reports on the divisions of the work indicated:

Antenna Theory (S. A. Schelkunoff)
Testing Methods (George Sinclair)
Microwave Antennas (L. C. Van Atta)
Broadcasting and Other Types of Communications (W. S. Duttera)
Air Navigation Systems (Harry Diamond)
Television Antennas (G. H. Brown)
Testing Television Transmission Lines and Antennas (D. B. Sinclair)
Annual Review (J. C. Schelleng)

Antennas

Date.....January 23, 1946
Place.....Hotel Astor, New York City
Acting Chairman...W. S. Duttera

Present

W. S. Duttera, *Acting Chairman*

Cledo Brunetti	S. A. Schelkunoff
D. W. Epstein	J. C. Schelleng
Sidney Frankel	D. B. Sinclair
E. C. Jordan	George Sinclair
D. C. Ports	Carl E. Smith (*guest*)

P. H. Smith

The subcommittees reported on the work being done in the following fields: Testing Methods; Broadcasting and Other Types of Communication; and Testing Television Transmission Lines and Antennas.

Electron Tubes

Date.....October 24, 1945
Place.....Editorial Department, I.R.E., New York City
Chairman....R. S. Burnap
Secretary....R. L. Freeman

Present

R. S. Burnap, *Chairman*
R. L. Freeman, *Secretary*

W. G. Dow	J. A. Morton
T. T. Goldsmith, Jr.	L. S. Nergaard
R. F. Guy (*guest*)	G. D. O'Neill
L. B. Headrick	H. J. Reich
D. E. Marshall	A. L. Samuel
I. E. Mouromtseff	J. R. Steen

C. M. Wheeler

The Committee expressed dissatisfaction with the name "Technical Committee on Vacuum Tubes" and recommended the name "Technical Committee on Electron Tubes."

The subcommittee on Advanced Developments recommended that the prepared "Proposed Standards on Ultra-High-Frequency Electronics" be published at an early date.

Definitions and methods of testing submitted by the Cathode-Ray-Tube subcommittee and the Small-High-Vacuum-Tube subcommittee were considered.

Facsimile

Date.....November 20 and December 4, 1945
Place.....Editorial Department I.R.E., New York City
Chairman....C. J. Young

The committee reported that good progress has been made in bringing up to date Definitions of Terms. Two subcommittees were set up: Terminal Equipment, E. F. Watson, *chairman;* and Transmission, H. G. Ressler, *chairman.*

Frequency Modulation

Date.....January 23, 1946
Place.....Hotel Astor, New York City
Chairman.....C. C. Chambers

Present

C. C. Chambers, *Chairman*

R. A. Biggar	D. L. Jaffe
M. G. Crosby	F. J. Kelley (observer)
W. F. Goetter	V. D. Landon
A. C. Goodnow	C. T. McCoy (representing D. B. Smith)

The definitions in the report were discussed, and recommendations were made to change some of the terminology.

The personnel of the subcommittees is as follows:

Receivers

J. E. Brown — V. D. Landon
C. T. McCoy (representing D. B. Smith)

Transmitters

W. F. Goetter — M. H. Jennings
A. C. Goodnow — J. E. Young

Pulse Modulation

M. G. Crosby, *Chairman*
E. M. Deloraine (or alternate) — C. T. McCoy
R. D. Kell — Bertram Trevor

RADIO RECEIVERS

Date.....October 16, 1945
Place.....Editorial Department I.R.E., New York City
Chairman.....D. E. Foster
Secretary, *pro tem*..H. P. Westman

Present

D. E. Foster, *Chairman*
H. P. Westman, Secretary, *pro tem*
G. L. Beers — Garrard Mountjoy
C. J. Franks — H. O. Peterson
R. M. Wilmotte

The committee discussed the report on "Methods of Testing Frequency-Modulation Broadcast Receivers." As it was required to prepare an annual review on radio receivers, various members of the committee were assigned to search specific publications for some of the material needed.

RADIO RECEIVERS

Date.....January 23, 1946
Place.....Hotel Astor, New York City
Chairman.....D. E. Foster

Present

D. E. Foster, *Chairman*
G. L. Beers — J. K. Johnson
L. F. Curtis — Garrard Mountjoy
C. J. Franks — E. D. Passow (representing J. E. Brown)

The committee discussed the draft proposal on "Methods of Measurement of Frequency-Modulation Receivers" which had been received from committee members and from the Radio Manufacturers Association.

The chairman reported on a meeting he had had with the chairman of the Radio Manufacturers Committee on Very-High-Frequency Receivers relative to the RMA data sheet for reporting measurements on such receivers. At that meeting, the RMA decided on a data sheet and to use the I.R.E. test methods as drawn up by the Committee on Radio Receivers.

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NAB Committees

The following membership list, made available through the courtesy of Mr. Howard Frazier, on behalf of the National Association of Broadcasters Engineering Committee, will be of interest to our readers.

Executive Engineering Committee

(The personnel of the N.A.B. District Engineering Committee is identical to that of the N.A.B. Executive Engineering Committee)

G. Porter Houston, *Chairman*
Radio Station WCBM
3000 Manhattan Avenue
Baltimore, Maryland

J. B. Fuqua
Radio Station WGAC
Augusta, Georgia

William B. Lodge
Engineering Department
Columbia Broadcasting System
485 Madison Avenue
New York, New York

Karl B. Hoffman
Radio Station WGR
Buffalo, New York

O. B. Hanson
National Broadcasting Company
30 Rockefeller Plaza
New York, New York

Howard S. Frazier, *ex-officio*
National Association of Broadcasters
1730 Eye St., N.W.
Washington 6, D. C.

District 1—Richard Blackburn
Radio Station WTHT
983 Main Street
Hartford 1, Connecticut

District 2—Frank V. Bremer
Technical Director
Radio Station WAAT
11 Hill Street
Newark 1, New Jersey

District 3—Louis E. Littlejohn
Chief Engineer
Radio Station WFIL
Philadelphia, Pa.

District 4—

District 5—W. Walter Tison
Radio Station WBRC
Birmingham, Alabama
Mailing Address:
901 S. Newport
Tampa, Florida

District 6—J. D. Bloom, Jr.
Chief Engineer
Radio Station WWL
New Orleans, Louisiana

District 7—Lester H. Nafzger
Chief Engineer
Radio Station WBNS
33 North High Street
Columbus, Ohio

District 8—

District 9—Oscar C. Hirsch, Owner
Radio Station WKRO
Cairo, Illinois
Mailing Address:
Radio Station KFVS
Cape Girardeau, Missouri

District 10—Mark Bullock
Chief Engineer
Radio Station KFAB
Sharp Building
Lincoln, Nebraska

District 11—

District 12—K. W. Pyle
Radio Station KFBI
Wichita, Kansas

District 13—Frank Jones
Chief Engineer
Radio Station KGKL
San Angelo, Texas

District 14—Robert Owen
Radio Station KOA
Denver, Colorado

District 15—George Greaves
Chief Engineer
Radio Station KPO
San Francisco, Calif.

District 16—Ralph G. Denechaud
Radio Station KECA
1440 N. Highland Avenue
Los Angeles 28, California

District 17—Louis S. Bookwalter
Radio Station KOIN
Portland, Oregon

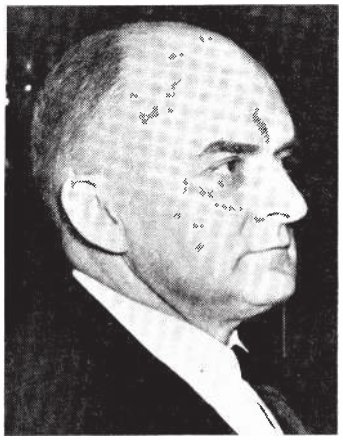
FRANK M. DAVIS

Frank M. Davis

Frank M. Davis (M'44), general manager of the Collins Radio Company's research and engineering division, Cedar Rapids, Iowa, died on February 4, 1946. Mr. Davis, an early amateur radio operator, was born in Monett, Missouri, on February 13, 1912. He received the B.S. degree in electrical engineering from the University of Arkansas in 1934 and later joined the Collins staff, subsequently becoming a member of its Board of Directors. He became widely known for his research and development work in the radio communications field and was recognized by members of the War and Navy departments for his leadership in important war projects.

Mr. Davis was a member of the American Institute of Electrical Engineers and the Acoustical Society of America. A charter member of the Cedar Rapids Section of the I.R.E., he became chairman during the first year of its formation.

I.R.E. People



JAMES G. BLACK

PHILIPS' APPOINTMENTS

O. S. Duffendack (SM'44), president of Philips Laboratories, Inc., Irvington, New York, has announced the appointment of James G. Black (A'45) as chief of the miscellaneous projects and analytical laboratories division, and George A. Esperson (A'34) as associate physicist of the microwave section.

Dr. Black, who received his Ph.D. degree from the University of Michigan in 1929, recently completed work on an important secret project for the National Defense Research Committee. Mr. Espersen has been transferred from Philips' plant at Dobbs Ferry, New York, where he was tube division engineer.

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JOHN ALTMAYER

John Altmayer (A'45), for many years associated with the production of radio and electronic precision parts, has become president of the newly formed Asco Corporation of Cleveland, Ohio. The company has been established for the manufacture of radio, television, electronic, mechanical, and electrical components.

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GEORGE A. ESPERSEN

RMA ENGINEERING DEPARTMENT

COMMITTEES

The Radio Manufacturers Association Engineering Department is engaged in numerous projects of importance, and of interest to the membership of the I.R.E. There are accordingly presented below lists of the various engineering groups within the RMA Engineering Department and their respective chairmen.

TRANSMITTER SECTION

Committee	Chairman
Executive	J. J. Farrell
Amplitude-Modulation Broadcast Transmitters	M. R. Briggs
International Broadcasting	H. Romander
Satellite Transmitters	H. S. Frazier
Frequency Modulation Broadcast Transmitters	R. H. Williamson
Antennas	T. M. Bloomer
Studio-to-Transmitter Links	J. F. Wilcox
Television Transmitters	C. A. Gunther
Program Transmitters	J. E. Keister
Antennas	H. E. Gihring
Relays	C. A. Gunther
Studio Facilities	J. C. Ferguson
Co-ordination Panel	H. B. Fancher
Audio Facilities	R. A. Miller
Communication and Marine Aids	E. Ports
Point to Point	H. R. Dyson
Marine Communication	L. H. Lynn
Fixed Stations	F. A. Polkinghorn
Mobile Stations	F. A. Polkinghorn
Navigational Aids	G. H. Phelps
Direction Finding	P. A. D'Orio
Obstacle Detection	J. Rankin
Loran	R. C. Ferrar
Aeronautical Radio	H. B. Fischer
Instrument Landing	H. Busignies
Navigation	R. R. Welsh
Private Flying	S. Nesbitt
Communication	H. B. Fischer
Emergency Services	D. E. Noble
Transmitters	F. D. Budelman
Receivers	G. M. Brown
Point-to-Point Relay	H. R. Dyson
Facsimile and Radio Type	*
Selective Calling	W. E. Reichbe
Noise (Ignition)	*
Bandwidth	*
New Applications	*
Systems Standards of Good Engineering Practice	W. R. Young
Transmitter Components	D. G. Little
Crystals	C. F. Baldwin
Dynamotors	*
Vibrators	*
Transformers	Reuben Lee
Batteries	*
Resistors	H. A. Cooke
Capacitors	R. W. Orr
Tube Sockets	H. R. Terhune
Connectors	S. J. Holland
Instruments	O. S. Meixell
Solid Dielectric Radio-Frequency Cables	A. J. Warner
Facsimile	J. N. Whittaker

* Chairman not yet appointed.

SOUND EQUIPMENT SECTION

Committee	Chairman
Executive	H. S. Knowles
Sound Systems	O. L. Angevine, Jr.
Distribution	S. B. Hughes
Mixers and Terminal Impedances	J. R. McCraigh
Panels, Racks, and Associated Equipment	R. F. Shea
Amplifiers	A. N. Curtiss
Speakers	W. A. Ellmore
Microphones	F. F. Romanow

SPECIAL ELECTRONIC-EQUIPMENT SECTION

Committee	Chairman
Executive	P. K. McElroy
Frequency-Modulation Receiver Testing	J. Minter
Frequency-Modulation and Television Test Equipment	D. B. Sinclair

RECEIVER SECTION

Committee	Chairman
Executive	D. D. Israel
Executive, Components Group	H. C. Forbes
Fixed Capacitors	J. I. Cornell
Electrolytic Capacitors	J. Hood
Mica Capacitors	A. DiGiacomo
Paper Capacitors	L. Kahn
Variable Air Capacitors	H. D. Sarkis
Sockets	S. DelCamp
Dry Batteries	H. J. Mason
High-Frequency Cores	H. A. Williams
Characteristics	H. Benner
Ceramic Dielectric Capacitors	J. D. Heibel
Acoustic Devices	W. A. Ellmore
Vibrating Interrupters and Rectifiers	K. M. Scafer
Switches	C. Rainwater
Variable Control Resistors	H. W. Rubinstein
Fixed Composition Resistors	D. S. W. Kelly
Wire-Wound Resistors	J. Marsden
Power Transformers	A. Helgason
Standardization of Laminations and Mounting Dimensions	R. J. Horstmann
Audio Transformer Standards	A. E. Chettle
Vibrator Transformer Standards	P. J. Koppe
Plug-in Resistors	G. Mucher
Radio-Frequency and Intermediate-Frequency Transformers	F. G. Webber
Broadcast and International Short-Wave Receivers	P. Craig
Executive, Television Receivers	I. J. Kaar
Television Receivers	I. J. Kaar
Standards of Good Engineering Practice	D. W. Pugsley
Optics	I. G. Maloff
Antennas and Transmission Lines	H. Selvidge
Special Components	S. C. Spielman
Vehicular Receivers	*
Very-High-Frequency Receivers	G. E. Gustafson
Executive, Phonograph Combinations and Home Recording	F. C. Young
Phonograph Combinations and Home Recording	F. C. Young
Phonograph Records	H. I. Reiskind
Record Changers, Etc.	H. Davis
Disk Home Recorders	L. V. Wells
Magnetic Recorders	W. A. Ellmore
Minimum Standards for Export Receivers	L. M. Clement
Vehicle Radio Interference	K. A. Chittick
Receiver Susceptibility	M. Levy
Measurements and Instrumentation	J. Minter
Vehicle Radio Interference (Society of Automotive Engineers)	P. J. Kent
Safety	W. Vassar
Transformer Isolated Receivers	A. C. Miller
Direct Connected Receivers	K. E. Hassell
Phono Combinations and Recorders	H. E. Kranz
Television Receivers	A. Wright

* Chairman not yet appointed.

JOINT ELECTRON-TUBE ENGINEERING COUNCIL

Committee	Chairman
Council	O. W. Pike
Staff	K. C. DeWalt (C. of S.)
High-Vacuum Power Tubes	K. C. DeWalt
Glass Standardization	H. S. Lovatt
Mechanical Inspection	H. L. Thorson
Magnetrons	J. H. Findlay
Gas Tubes	V. L. Ronci
Vacuum-Sealed Devices	H. W. Parker
Crystal Rectifiers	H. Heins
Phototubes	A. M. Glover
Receiving Tubes	A. K. Wright
Cathode-Ray Tubes	I. E. Lempert
Characteristics	A. J. Harcher
Line Width and Modulation Characteristics	L. B. Headrick
Glass Characteristics	J. R. Beers
Phosphor-Screen Characteristics	L. B. Headrick
Type Designations	R. S. Burnap
Mechanical Standardization	E. F. Peterson
Shock and Vibration	V. L. Ronci
Water-Cooled Types, Anodes and Gaskets	M. Youdin
Pool Types	D. E. Marshall
Electron-Tube Packaging	R. S. Bolan
Marking	Harvey Fay
Sampling Procedure	S. W. Horrocks

I.R.E. People

EDWARD L. BOWLES

EDWARD L. BOWLES

Edward L. Bowles (A'22–M'28–SM'43) was awarded the Distinguished Service Medal on November 14, 1945, for exceptionally meritorious service to the United States Government.

Dr. Bowles received the B.S. degree from Washington University in 1920 and the M.S. degree in electrical engineering from the Massachusetts Institute of Technology in 1922. The degree of Doctor of Science was awarded him by Norwich University in 1945. He was professor and head of electrical communications at M.I.T. and secretary of the microwave committee of the National Defense Research Committee.

In 1942, Dr. Bowles was appointed expert consultant to the Secretary of War to advise on radar policy. He was responsible for establishing experimental and operational Army Air Force units to combat the submarine menace off the Atlantic seaboard, and for the plans carried to President Roosevelt. As a result of the comprehensive anti-submarine proposal, General Arnold requested that Dr. Bowles assume over-all supervisory responsibility for A.A.F.'s communications comprising all forms of radar, countermeasures, radar aids to fire control

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DAVID B. SMITH

I.R.E. People

MAXWELL H. A. LINDSAY

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and bombing, radio and radar aids to navigation, and electronics. In 1944, he became special consultant to the Commanding General, A.A.F. General Marshall then called upon Dr. Bowles for assistance in the British "buzz-bomb" assaults. He formulated a plan leading to the dispatch of special antiaircraft equipment which functioned under conditions of complete invisibility when fighter planes were helpless against the missiles.

Included in Dr. Bowles' activities were the planning for the radar bombing by the 8th, 15th, and 20th Air Forces, and the 315th Air Wing was the result of plans originated by him for General Arnold. During the war, Dr. Bowles had representatives on General Eisenhower's and General MacArthur's staffs and on those of the major Air Force commanders in the European, Pacific, and China-Burma theaters to assist in the introduction and development of radar. In January, 1945, upon nomination of the Secretary of War, Dr. Bowles was appointed an Army member of the National Academy of Sciences and National Research Council Board for National Security.

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DAVID B. SMITH

David B. Smith (A'35–SM'44) has recently been appointed vice-president in charge of engineering of Philco Corporation.

In 1933, Mr. Smith was graduated from the Massachusetts Institute of Technology with the degrees of S.B. and S.M. in electrical engineering. The following year, he joined Philco as patent engineer after which he was placed in charge of an advanced-studies group in the research and engineering department. Appointed technical consultant to the vice-president in charge of engineering in 1938, he became director of research in 1941. In this capacity, he directed the microwave and ultra-high-frequency research that led to the production of many types of airborne radar used by the United States Army and Navy.

Visiting Engineers

It has been suggested that visitors from engineering societies abroad get in touch with The Institute of Radio Engineers, the Societe Francaise, the Institution of Electrical Engineers, and other similar engineering organizations with the thought that these visitors be invited to present papers before meetings of these scientific bodies. In case visitors are not prepared to present formal papers, it has been suggested that they be invited to address the meetings informally.

Mr. Smith was a member of the Radio Manufacturers Association's Television Committee, and chairman of Panel 9 of the National Television System Committee. Elected to the Radio Technical Planning Board, he served as chairman of its Television Panel, and in 1945, he was named chairman of RMA's Television System Committee. Mr. Smith is also a member of Tau Beta Pi. Presently chairman of the Philadelphia Section of the I.R.E., Mr. Smith is credited with many patents and patent applications covering inventions in radio, radar, and television.

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MAXWELL H. A. LINDSAY AND FINLEY W. TATUM

Maxwell H. A. Lindsay (A'30) has been appointed assistant chief engineer, and Finley W. Tatum (A'43) has been named engineering supervisor of American District Telegraph Company, New York City.

Born in St. John's, Newfoundland, Mr. Lindsay received the B.S. degree from Mt. Allison University, New Brunswick, Canada, in 1925, and the M.S. degree in mathematical physics from Columbia University in 1930. While an undergraduate at Mt. Allison, he was physics instructor and assistant in descriptive geometry. From 1925 to 1926, he was instructor in the physics

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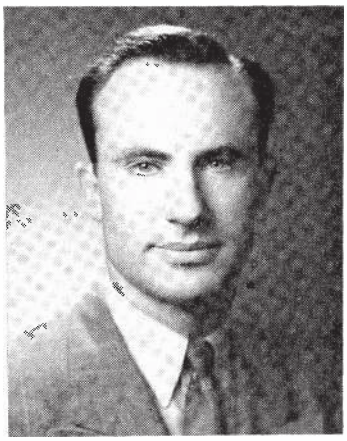

Leon Trice

PAUL M. REYLING

FINLEY W. TATUM

department of the Massachusetts Institute of Technology, after which he became a member of the technical staff in the physical laboratory and radio department of Bell Telephone Laboratories, Inc. In 1932, he joined the engineering department of the American District Telegraph Company, and he became engineering supervisor on intrusion detection systems and electronic equipment in 1935. Mr. Lindsay's work has involved the development and application of photoelectric, sound, and capacitance principles to the electrical protection of establishments and property, and he holds many patents in the field of protective signaling. He is a member of the Acoustical Society of America and the International Municipal Signal Association.

Mr. Tatum was born in Kent, Texas, and was graduated from Columbia University with a B.S. degree in electrical engineering in 1935. Later that year, he joined the plant department of the American District Telegraph Company and, in 1936, entered the engineering department to handle the development of various protective signaling systems. He has been in charge of electronic training courses for the company's personnel since 1944. Mr. Tatum is a member of the American Institute of Electrical Engineers and is a licensed professional engineer.

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PAUL M. REYLING

Paul M. Reyling (M'44) has been named production and engineering manager of Freeland and Olschner Products, Inc., of New Orleans, Louisiana, where he will manage the tube plant and supervise tube-development projects.

Mr. Reyling, who received his B.S. degree in electrical engineering from Brooklyn Polytechnic Institute, was affiliated with the Radio Corporation of America Manufacturing Company at Harrison, New Jersey, and Lancaster, Pennsylvania. He then became vacuum-tube engineer with Federal Telephone and Radio Corporation at Clifton,

I.R.E. People

New Jersey, where he directed the development and production of large vacuum tubes. Before joining Freeland and Olschner, he was on the staff of the Tennessee Eastman Corporation as senior engineer in charge of the vacuum-tube program for the Oak Ridge atomic-bomb project.

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RCA Promotions

David Sarnoff (A'12–M'14–F'17), president of the Radio Corporation of America, recently announced the appointment of E. W. Engstrom (A'25–M'38–F'40) as vice-president in charge of research of RCA Laboratories; C. B. Jolliffe (M'25–F'30), executive vice-president in charge of RCA Laboratories; Meade Brunet (M'26–SM'43), vice-president in charge of RCA Victor engineering products; J. W. Murray (A'45), vice-president in charge of RCA Victor records; and T. H. Mitchell (SM'45), executive vice-president of RCA Communications, Inc.

A graduate of the University of Minnesota, Mr. Engstrom served for thirteen years in research positions at RCA. He became research director of RCA Laboratories and supervised research and engineering which resulted in wartime advances in radar, television, radio, and other electronic developments.

Dr. Jolliffe received the B.Sc., M.S., and LL.D. degrees from West Virginia University, and the Ph.D. degree from Cornell University. He was physicist in the Bureau of Standards' radio section and later became chief engineer of the Federal Radio Commission. He first joined RCA as engineer-in-charge of its frequency bureau, and, subsequently, he was named chief engineer of RCA Laboratories and assistant to the president of RCA Victor. In 1942, Dr. Jolliffe became chief engineer of RCA Victor at Camden, New Jersey.

Mr. Brunet, a graduate of Union College, joined RCA in 1921 and had charge of production and distribution of RCA Radiotrons and Radiolas. He was appointed manager of the Radiola division, advanced to sales manager, and later became general manager of engineering products.

A Columbia University graduate, Mr. Murray first joined RCA Victor as general manager of the phonograph-record commercial division and later was promoted to general manager of RCA Victor records. From 1932 to 1939, he was engaged in the sales and manufacture of phonograph records in the Far East, which activities he continued upon his return to the United States.

Mr. Mitchell served as vice-president and general manager of RCA Communications, Inc., before his new appointment as executive vice-president.

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Frank H. R. Pounsett

The appointment of Frank H. R. Pounsett (A'26–SM'44) as chief engineer of the Stromberg-Carlson Company, Ltd., Toronto, Canada, has recently been announced by Ralph A. Hackbusch (A'26–M'30–F'37), vice-president and managing director.

Mr. Pounsett, a graduate in electrical engineering of the University of Toronto, was engineer for the De Forest Crosley Radio Company. He served as chief engineer in the radio division of the Stewart-Warner-Alemite Corporation, and later held the same position on the staff of Research Enterprises, Ltd. Mr. Pounsett is a registered professional engineer and holds the chairmanship of the Toronto Section of the I.R.E.

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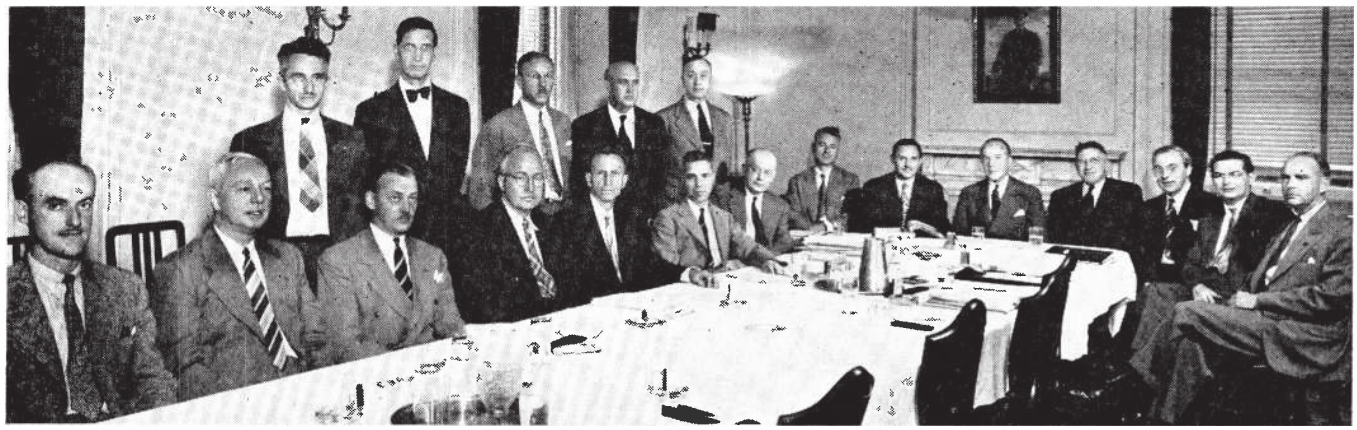
G. Emerson Pray

G. Emerson Pray (M'41–SM'43) has purchased the Tuck Electronic Corporation of New York and New Jersey engaged in the development of electronic and electromechanical devices and equipment.

Mr. Pray received the E.E. degree from Rensselaer Polytechnic Institute and performed graduate work at Rutgers University. He joined RCA Laboratories, Rocky Point, New York, in 1928 where he engaged in the development of frequency modulation, high-speed transmitter keying, very-high-frequency wave propagation, and resonant line oscillators. From 1931 to 1935, while with the Signal Corps Laboratories, Fort Monmouth, New Jersey, he developed the first superheterodyne receiver adopted for use by the United States Army.

As assistant chief of the radio research section of the Naval Research Laboratory, Anacostia, D. C., Mr. Pray completed the first successful Navy radar receiver. He became chief engineer and assistant to the vice-president of Airplane and Marine Instruments, Inc., Clearfield, Pennsylvania, in 1941, where he developed the Sono-Radio Buoy, the static direction finder, and the automatic cathode-ray direction finder.



Some Members of Canadian Radio Technical Planning Board at Meeting in Montreal

Seated, left to right—W. G. Southam and A. Reid, American Radio Relay League, Canadian Section; B. C. Fairfield and A. S. Runciman, Canadian Electrical Association; H. W. Haberl, Quebec H.E.P.C.; R. V. MacAulay, Telephone Association of Canada; L. S. Payne (M'16–SM'43), chairman, Panel A; G. M. Olive (M'43), Canadian Broadcasting Corporation; W. W. Richardson, secretary-treasurer; R. M. Brophy, president; R. A. Hackbusch (A'26–M'30–F'37), vice-president, Radio Manufacturers Association of Canada; A. B. Oxley (A'25–M'33), general co-ordinator; G. J. Irwin (A'35–M'37–SM'43), co-ordinator; and A. B. Hunt, Canadian Electrical Manufacturers' Association.

Standing, left to right—S. Sillitoe (A'35) chairman, Panel C; J. F. Neild, Canadian Transit Association; D. G. Geiger (A'31–M'45–SM'45), Telephone Association of Canada; F. S. Howes (A'37–M'43–SM'43), Institute of Radio Engineers; and J. A. Brass, Railway Association of Canada.